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Physiology and
Histology.

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SYLLABUS

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OF

THE LECTURES

ON

PHYSIOLOGY AND HISTOLOGY;

INCLUDING THE

OUTLINES OF COMPARATIVE ANATOMY,

DELIVERED AT THE

University of Virginia,

BY

J. L. CABELL, M.D.

ANNEX ANNEX

PRINTED FOR THE USE OF THE MEMBERS OF THE CLASS.

UNIVERSITY OF VIRGINIA:—McKENNIE & SON.

1853.

(1) The objects of science in their most
enlarged sense & indicate the fundamental
grounds of distinction between Physical &
Mental Science (2) State the twofold sub-
-division of Physical science & the dis-
-tinct objects of each branch (3) State
distinctly the special object of Physiology
(4) State with illustration the several sources
of evidences on which the connection be-
tween organs & functions [illegible] — is dis-
covered & indicate their relative value
(5) State with illustrations the several
items of knowledge necessary for the scien-
tific explanation or complete elucidation
of a function (6) Explain the inductive
method of arriving the general truths of [illegible]
simple and complex cases (7) present
in a tabular form the results of anatom-
ical analysis of the human body so as
of the [illegible] to indicate the dis-
tinct object of [illegible] & general anat
(8) Explain what is meant by proximate
[illegible] ~~[illegible]~~ Elements as contra-
distinguished from ultimate & classify the
former according to their physiological
relations (9) Explain what is meant
by [illegible] Elements & enumerate the
[illegible] forms of [illegible]

ERRATA.

The author's want of practice in correcting proof caused him to overlook many errors of the press, in the first impression, and the distance between his residence and the city where these pages were printed precluded the possibility of a second correction. Accordingly the existing errors are very numerous, but to avoid making the list too long, he omits such of them as the intelligent reader will readily correct for himself, as where a single letter is omitted, or where the singular number is used instead of the plural, and *vice versa*, of both classes of which there are many examples.

Page 6, line 11, for "blood, plasma" read "blood-plasma."
15, line 6, for "secretive" read "secreted."
16, line 14, for "tenacity" read "tonicity."
17, line 37, for "Chloride" read "Hydro-chlorate."
19, XII class, for "MEMBRANE. FIBROUS" read "membrano-fibrous."
22, line 18, for "contractible" read "contractile."
22, last line, for "*Physical*" read "*Physiological.*"
23, line 1, of caption, for "ORGANIC" read "ANIMAL."
30, line 22, for "between" read "being."
35, last line, for "both" read "each."
39, line 5, from the bottom, for "*Homiptera*" read "*Hemiptera.*"
49, line 7, for "AMPHINEURTA" read "AMPHINEUSTA."
49, line 10, for "*Axploti*" read "*Axolotl.*"
59, line 24, for "physical" read "psychical."
59, line 32, for "same" read "several."

(84) Phenomena of protracted fasting and absolute starvation

(85) Physiological effects of healthy digestion

(86) Effects resulting from the habitual use of aliments defective in quality or quantity.

(87) Effects of undue repletion of the stomach

(88) Effects resulting from the frequent or habitual digestion of more food than is needed by the system

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PREFACE.

A SYLLABUS of Lectures, consisting of the mere heads of the topics which are to be fully expounded in the oral discourses of the teacher, can have no value except to the students who listen to these discourses. It can, therefore, scarcely be necessary that I should disclaim all intention of *publishing* these pages, which are *printed* for the exclusive use of the members of my class. It had long been my custom to write upon a blackboard the heads of the topics discussed in each lecture, which served the two-fold purpose of lessening the difficulty of taking notes, and of facilitating references to the text-books and other authorities that might be occasionally quoted. The task of copying these notes from a blackboard, which from the arrangement of the room was unavoidably placed in an unfavorable position as regards the light, was found to be so onerous, that I have felt myself constrained, by the urgent solicitation of many members of the class, to have them printed.

In view of the single use for which they are designed, I have not regarded it as necessary or important to mark off the subjects by any formal arrangement of Sections and Chapters, contenting myself with merely numbering the paragraphs consecutively from the beginning to the end. For the same reason I have deemed it unnecessary to prepare a "Table of Contents." Those who attend

the lectures will readily understand the principle governing the arrangement of the subjects, and will therefore easily know where tofind the appropriate place for each topic.

It will be observed, that Histology and the Outlines of Comparative Anatomy are taught with direct reference to their applications to HUMAN PHYSIOLOGY, and, indeed, as a necessary part of a complete exposition of the latter subject. Accordingly, the consideration of these topics is introduced into the body of the work, after a preliminary exposition of certain generalities on the nature and objects of Physiological Science, and before the discussion of the Special Physiology of the several functions.

In several instances I have deemed it expedient to abandon, for one or more paragraphs, the form and style of a *syllabus*, and to substitute a more continuous statement of matter in hand, especially when this embraced abstract generalities not fully expounded in the text-books, my experience as a teacher having satisfied me that most youthful minds find much difficulty in apprehending such generalities on a single hearing, or with only a compendious statement of them in the form of a syllabus for revisal. But in the main I have conformed to the principle of a syllabus, and have presented only short summaries of the subjects which are amplified and illustrated in the lectures. The almost exclusive reference to Carpenter's Elements of Physiology, and Kirkes & Paget's Human Physiology, is explained by the fact that these works are both used as text-books.

SYLLABUS OF LECTURES

OF COMPARATIVE ANATOMY AND PHYSIOLOGY.

OF PHYSICAL SCIENCE IN GENERAL.

1. Definition of SCIENCE in its most enlarged sense, as comprising all attainable knowledge of natural bodies and phenomena, when such knowledge is "*orderly and methodically arranged.*" Distinction between MENTAL and PHYSICAL SCIENCE.

2. Two-fold subdivision of physical science into NATURAL HISTORY and NATURAL PHILOSOPHY. Natural history views objects *as they exist in space*, and simply observes and narrates phenomena as they are directly addressed to the senses. It should, indeed, arrange and classify objects according to their relations of form, colour, structure, and other similar qualities, but it does not speculate upon their active phenomena viewed as *causes and effects*, which is the appropriate province of natural philosophy. Illustrative examples: zoology, botany, and anatomy, are branches of natural history, while mechanical philosophy, chemistry, and physiology, are branches of natural philosophy.

3. But inasmuch as the aim of natural history is to describe and classify objects, it may take cognizance of the actions and changes of bodies so far as they *characterize* the latter, provided it does not seek to *explain* such actions, but only adopts them as facts that may be of use in furnishing the basis of a natural classification.

An acquaintance, to a certain extent, with natural history, must precede the study of natural philosophy, since we must collect, verify, and classify facts, before we can *interpret* or *explain* them. In natural history we do not go beyond the observation and classification of phenomena. In philosophy we begin with natural history, (collection of facts,) and regarding phenomena as *effects*, aim to *explain them by the discovery of causes and laws.*

EXPOSITION OF THE SPECIAL OBJECT AND METHODS OF THE STUDY OF PHYSIOLOGY.

4. PHYSIOLOGY.—That branch of natural philosophy which seeks to discover the *laws under which the actions of living beings are performed.* Animal physiology may be studied with reference exclusively to the actions of the human frame, (HUMAN PHYSIOLOGY,) or with reference to the whole animal series, (COMPARATIVE PHYSIOLOGY.) Brief statement of the importance of the study of comparative animal and vegetable physiology.

5. Two classes of facts embraced in the narrative division of physiology, namely, (1) the characters of the ORGANS or material instruments by which the actions of life are manifested, and (2) the FUNCTIONS or special operations of the several organs. The investigation of the first of these two classes of facts is the special object of ANATOMY. Thus one branch of the physiological problem consists in seeking to establish the connexion between organs and their functions, and may be thus stated: *an organ being given, to discover its action or function, or conversely, a vital act being recognised, to discover the organ or organs concerned in its execution. Examples*:

6. EVIDENCE ON WHICH FUNCTIONS ARE ASSIGNED TO GIVEN ORGANS. (a) *Evidence derived from direct observation.* (b) *From experiments*—sources of fallacy in deriving *positive* conclusions from experiments on living animals of a high grade. *Negative* information from this source more reliable. (c) *From pathological observation*—why more reliable than that derived from the effects of sudden and artificial changes. (d) *From comparative anatomy.* The contemplation of the anatomical structure of a single species throws little light on the investigation of functions, except where these are purely mechanical, in which case we note the adaptation of the organ on mechanical principles for a special use. The *comparison* of extensively varied types of animal forms, all executing substantially the same fundamental phenomena of life, enables us to ascertain what are the essential constituents of each organ, and what are the other essential conditions of its action. Comparative anatomy thus furnishes "so many kinds of experiments ready prepared by nature."

7. After assigning to an organ its appropriate function, or after having traced an observed action to the organs concerned in its manifestation, it remains to *explain* or *interpret* it, which constitutes the second branch of the problem. Only legitimate sense in which a natural phenomenon can be said to be *explained*—elucidation of the conditions under which it is exhibited. Systematic arrangement of those conditions under the following heads—(a) *Proximate cause*, or that inherent property of matter to which the phenomenon in question may be traced as an *ultimate fact.* Examples—The action of muscles in displacing parts, traced to a peculiar property inherent in muscular fibre, by virtue of which the fibre, under certain circumstances, becomes suddenly and actively shortened. The ascent of the piston in a steam-engine, traced to the expansive power of steam, a property inherent in that material, and exhibited under certain circumstances.

(b) *Exciting causes, or stimuli.*—The power of contracting, which is inherent in muscular fibre, yet requires to be *excited* or *stimulated* as a condition of its manifestation. As the agencies which fulfil this office, may be said in a certain sense to *cause* or *occasion* the resulting action, they are indifferently termed EXCITING, OCCASIONAL or DETERMINING CAUSES, or STIMULI.

(c) *Laws.*—Apart from the foregoing, there are other conditions which indicate the *mode* and *especially some limitation* of the effects resulting from the assigned causes, and these are termed LAWS, as being expressions of the will of the Author of Nature. Ultimate properties identified by their laws. Thus, to prove that apparently diverse phenomena are really due to the same proximate cause, it must be shown that they are governed by the same laws. Examples:—

(d) *Final causes.* As in attempting to explain the construction and operation of a complicated machine, we have not only to indicate the use or function of each separate part, and to show how such action depends on the properties inherent in its material, but must also point out the connexion between the independent actions of the separate parts and the workings of the machine as a whole, so in the study of Physiology we must show how the operation of the separate organs contribute to the general welfare of the organism by subserving special uses subordinate to that common end, and such uses are termed FINAL CAUSES. The contemplation of final causes presents to the rightly constituted mind incontestable evidence of intelligent foresight and contriving skill, and hence forms the basis of the science of NATURAL THEOLOGY. Final causes not to be substituted for physical causes. The former indicate the beneficent designs of Providence, the latter disclose the instrumental methods employed, under certain determinate conditions or limitations, by Infinite Wisdom to work out these designs.

8. METHOD OF ARRIVING AT POSITIVE RESULTS IN THE RESEARCH FOR CAUSES AND LAWS. Observation does not *directly and immediately* indicate causes and laws, but supplies the data which the mind spontaneously and intuitively groups in appropriate order according to natural relations, so as to *infer* from this comparison general facts or laws. Such act of inference is the main element in the INDUCTIVE process of thought, by which we discover the laws of nature. Illustration—Laws of human enactment made known by proclamation, oral or printed; laws of nature *discovered* only by observing facts, and from the uniformity of their sequence in the past, *inferring* a like uniformity in the future. Brief statement of some of the rules of procedure for facilitating the research by induction for the laws which govern complex phenomena. (a) Particular observations must be sufficiently numerous and extended, to eliminate sources of error. *Illustration.* (b) In assigning causes we may often avoid error by inquiring whether a suggested cause be *appropriate*, that is, whether on the ground of analogy it be likely to have such a relation with the effects to be explained. The assigned cause must be a *vera causa.* (c) Again it must not only be a *vera causa*, but it must be adequate in degree.

9. *Of the employment of the deductive process in the investigation of general truths.* Our inductions are often accompanied and aided by the *deductive process*, as when we make a provisional assumption, and having *deduced* the consequences involved in such

assumption, proceed to compare them with the observed phenomena, so as to verify or refute the hypothesis, thus anticipating the slower process of simple induction. Used in this way, the process of deduction may be made strictly subordinate to the most rigorous induction. But this logical artifice needs to be used with caution in the sciences that treat of vital phenomena, since in them the mathematics cannot be employed to verify or refute the assumption.

GENERAL VIEW OF THE CHEMICAL AND STRUCTURAL COMPOSITION OF THE HUMAN BODY.

10. The distinct subjects of inquiry in the two leading divisions of Human Anatomy, are exhibited in the following scheme, representing the successive stages of the anatomical analysis of the fabric.

(a) The body is resolved into a number of ORGANS of which the *form*, *weight*, *colour*, *situation*, *local connexions* and *structure* are to be determined.

(b) In investigating the *structure* of organs, these are resolved into their constituent *tissues*, a limited number of which are combined in various ways, so as to form all the different organs of the body.

} SPECIAL ANATOMY or ORGANOGRAPHY.

(c) In taking note of the anatomical characters of the several *tissues*, we observe that they too are compound structures, and resolve them into a small number of STRUCTURAL ELEMENTS or PRIMARY FORMS OF ORGANIZATION, such as *homogeneous membrane*, *fibres*, *cells*, *nuclei* and *granules*.

(d) Thus far the analysis is exclusively anatomical, and the properties of the material concerned are unchanged. By a different method of analysis, as the result of which the properties of tissues are wholly transformed, we reveal their CHEMICAL composition, exhibiting at the first stage certain PROXIMATE ANIMAL PRINCIPLES, such as *albumen*, *fibrin*, *gelatine*, *fatty principles*, &c., and by a further process reducing these to the *ultimate elements* of matter.

} GENERAL ANATOMY or HISTOLOGY.

N B. HISTOLOGY (*a description of tissues*) is not strictly synonymous with GENERAL ANATOMY, which comprises, in addition to the anatomy of the simple tissues, all the *generalities* which may be predicated of *classes of organs*, such as bones, muscles, glands, &c.

11. Definition of chemical or ultimate elements of matter, which by their various combinations make up all known material objects, such as gases, liquids, earths, stones, and the bodies of animals, and plants. Example: limestone may be separated into two proximate ingredients, namely, a gaseous body, which is driven off by a high temperature, called carbonic acid, and a white caustic solid, known as quick lime; but each of these ingredients is a compound, the former consisting of carbon and oxygen, and the latter of calcium and oxygen. These last named substances cannot be reduced any further, and are *presumed* to be elementary.

12. Sixty-one or two such elements, are found in the mineral kingdom, and only about *seventeen* ever enter into the composition of animal structures, namely, *oxygen*, *hydrogen*, *nitrogen*, *carbon*, *sulphur*, *phosphorus*, *chlorine*, *potassium*, *sodium*, *calcium*, *magnesium*, *iron*, *fluorine*, and occasionally *manganesium*, *silicon*, *aluminium* and *copper*. The first four are named *essential elements*, the others *incidental elements*.

13. PROXIMATE ORGANIC PRINCIPLES of determinate characters, are the products of chemical decomposition of organised structures, short of their *ultimate* analysis. Example: a substance known as animal jelly or GELATINE is separated from certain animal tissues by protracted boiling. It is, therefore, one of the constituents of animal flesh, but being itself a compound of carbon, oxygen, hydrogen and nitrogen, it is termed a *proximate principle*. The various proximate principles entering into the composition of the human tissues may be classified either according to their *chemical* or their *physiological* relations. See *Kirkes and Paget's Human Physiology*, chapter I. for the chemical classification. An arrangement founded on physiological relations is thus stated by *Carpenter* (Human Physiology, Ed. 1853).

(a) The *Histogenetic* substances destined to become part of the organised fabric by *progressive metamorphosis*.

(b) The *calorific* substances, which are either introduced into the body as components of the food, or which are formed within it, by the metamorphosis of the histogenetic substances, or of the components of the tissues themselves. These substances are destined to undergo oxidation, and thereby to generate heat, and are all of the *saccharine*, or of the *oleaginous* class, or are derivable from them by very simple transformations.

(c) The *components of the actual living tissues*.

(d) The *excrementitious substances* which are formed within the body as the *products of the disintegration, and retrograde metamorphosis of its tissues*, and which are on their way from these to the outlets of the excretory apparatus. They constitute a group of substances, which are intermediate in their chemical character between the foregoing and inorganic matter.

For a detailed account of the sensible character and chemical reactions of *albumen*, *caseine*, *gelatine*, *chondrine* and *fibrine*, and their relations to *proteine*, see Carpenter's Elements of Physi-

ology § 167 to § 187 inclusive. Other organic proximate compounds will be noticed in connection with the description of the tissues in which they exist.

B.—STRUCTURAL COMPOSITION OF THE HUMAN BODY.

14. The animal organism in its integrity as a living machine, consists of *fluids* and *solids*. The *fluids* divided into (a) FORMATIVE FLUIDS, as *lymph*, *chyle* and *blood* and (b) SECRETED FLUIDS, such as *bile*, *saliva*, *urine*&c., &c. The solids constitute the different tissues. Both fluids and solids are composed of certain STRUCTURAL ELEMENTS, which may be classified thus:

- (a) *Amorphous Elements*, which show no trace of structure, being simple and homogeneous.
  - (1) LIQUID BLASTEMA, such as the fluid blood, plasma.
  - (2) SOLID CYTOBLASTEMA, as the intercellular matrix of cartilage, &c.
  - (3) PRIMARY MEMBRANE, forming walls of *cells* and of the finest blood-vessels.
- (b) PRIMARY ORGANIC FORMS, which are so arranged as to constitute tissues of determinate structure, some of them being themselves composed of definitely arranged dissimilar parts.
  - (4) GRANULES . . . . *Free*, as in chyle, milk, or *inclosed*, as in pigment cells, or *imbedded*, as in bones and teeth.
  - (5) NUCLEI or CYTOBLASTS, minute vesicles with walls of simple membrane and usually inclosing, besides a pellucid fluid, one or more minute granules of a peculiar appearance, called *nucleoli*.
    - *Free nuclei*, either floating in a liquid, as those of gastric juice, or loosely imbedded in solid substance, as in the vesicular matter of the brain and spinal marrow.
    - *Attached nuclei*, either closely imbedded in homogeneous substance, or fixed to the surface of fibres or membranes, or finally inclosed in *cells*.
  - (6) *Cells*, which are vesicles of larger average size than nuclei. In their perfect condition they generally contain each a *nucleus* and sometimes two nuclei. A cell thus consists of a nucleus inclosed together with liquid contents in a secondary vesicle having homogeneous membranous cell-walls.
    - *Free* and either floating as those of *lymph*, *chyle and blood*, or loosely imbedded in solid or semisolid substance, as those of the grey matter of the brain, epithelium cells, &c.
    - *Cells* whose walls have coalesced while their cavities remain distinct.
    - *Cells* whose cavities have coalesced so as to form *tubules*.
    - *Fibre-cells*, or cells transformed into *solid fibres*.
    - *Cells* whose cavities are more or less obliterated by secondary endogenous deposit.
  - (7) *Primary fibres*, formed *directly* without cell-agency.

See Human Physiology by Kirkes and Paget, Chap. II.

GENERAL ANATOMY OF THE HUMAN TISSUES.

A. *Simple Fibrous Tissues.*

15. Anatomical characters of the white elementary fibre. Its occasional origin in the direct *fibrillation* of fibrinous plasma, independently of cell-agency—its occasional origin from transformed cells—its chemical composition and reactions—its uses. Carpenter's Elements, § 188–9, §180–183, § 193.

16. Anatomical characters of the *yellow fibrous element*—microscopic tests—chemical composition and reactions. Ib. § 190–192.

17. *General anatomy* of the tissues and organs composed exclusively of the *white fibrous element*, and hence termed the *white fibrous tissues.*

Distribution. Tendons of muscles. Most ligaments. Investing membranes of bones and many other organs. *Conformation*, funicular, fascicular, membraniform; *naked eye characters*, colour, polish, fibrous arrangement; *microscopic characters*, *physical properties*, *vital properties*, *chemical composition*, *uses.*

18. *General anatomy* of the *yellow fibrous tissues*, found pure and unmixed in the ligamenta sub-flava, ligamentum-nuchæ, vocal cords, and in a stratum of fibres constituting a part of the arterial tunics. Found inseparably mixed with the white fibrous element in areolar tissue, and with cartilage in the ear, nose, epiglottis, &c. For other characters, see Carpenter's Elements, loc. cit.

19. *Areolar tissue* formerly called *cellular tissue. Definition;* white fleecy body, composed of translucent and softish fibres, connecting the skin with the subjacent organs and these with one another. *Distribution;* subcutaneous, sub-mucous, subserous, intermediate and investing, interstitial, parenchymal or interlobular, &c. *Conformation;* arranged in masses whose outline is determined by the shape of the space they are to fill, and susceptible of being flattened into membranous fasciculi. *Structure;* fibres and lamellæ intersecting in various directions. *Microscopic characters.* Mixture of white and yellow elementary fibres; former predominating, latter of very variable dimensions, some being excessively minute, and wound spirally around the white band-like fibres. Other characters are such as would result from its composition as a mixture of the two fibrous elements.

20. *Serous membranes*, comprising also *synovial membranes.*—*Definition. Distribution. Conformation*, a membrane arranged in the form of a short sac, presenting a free surface, smooth and polished, and an adherent surface, with a subserous areolar tissue. *Structure:* next to the free surface a layer of *tessellated epithelium cells*, resting upon a basement primary membrane itself supported by *an areolar derm* very delicate, but condensed and nearly non-

vascular, the vessels not extending beyond the subserous lax areolar tissue; this last is generally lax and contains fat, but is sometimes dense and close. *Physical and vital properties—Uses.* Peculiarities of synovial membranes and of their relations with articular cartilages before and after birth.

21. MUCOUS MEMBRANES constituting the internal integument. *Distribution;* (a) alimentary tract and its glandular appendages. (b) Respiratory tract. (c) Lachrymal tract. (d) Genito-urinary tract. (e) System of glands and follicles opening on the skin. *Conformation;* membranes with a free, and an attached surface of variable thickness—free surface more or less *villous* except in the more delicate specimens, which approximate to serous membranes; attached surface areolar; body spongy; *colour* more or less reddish according to the different degrees of vascularity of different specimens; redness *uniform*, *ramiform*, or *punctiform*. *Structure:* next to free surface there is a layer of epithelium cells which may be tessellated, cylindrical, or spheroidal. This layer rests on a basement membrane supported by an areolar derm, which is commonly thicker than that of serous membranes and is generally very vascular; arrangement of the vessels in the villi; arrangement of vessels around the mouths of follicles; nerves of mucous membrane. *Physical and vital properties—uses.* See Carpenter's Elements, § 199 to § 205 inclusive.

B.—BASEMENT OR PRIMARY MEMBRANE.

22. *Definition.*—Three varieties: (1) simple amorphous membrane seemingly formed directly from the nutritive fluid, by a simple consolidation of a thin layer; (2) a membrane with minute granules imbedded in its substance, as if the blastema from which it was formed had included nuclear granules; (3) a membrane with distinct spots arranged at equal or variable distances, and having a tendency to break up into portions of equal size, as if it had been formed by the coalescence of cells whose cavities had been obliterated and their contents removed, but whose nuclei had continued to perform their peculiar functions. *Distribution:* on *all* the free surfaces of the body, beneath the epithelial or epidermic cells. *Uses* &c. See Carpenter's Elements, § 206 to § 209 inclusive.

C.—STRUCTURES COMPOSED IN PART OF SIMPLE ISOLATED CELLS.

23. *History* of an independent animal cell; its *structure;* albuminous cell-wall; contents variable, but generally include a nucleus which is itself vesicular and may contain a nucleolus. *Development*, in one of two modes; (1) from pre-existing cells, either by subdivision of parent cell, or by endogenous multiplication;

(2) by a new production of cells in an organizable plasma, which is then called CYTO-BLASTEMA. Carpenter, loc. cit. § 210 to § 213 inclusive.

24. FORMATIVE FLUIDS, CHYLE, LYMPH AND BLOOD. *Definition;* (a) notice of the anatomical characters of the cells, which are common to all of these fluids and which are variously named, *chyle corpuscles*, *lymph corpuscles*, and *white or colourless corpuscles of the blood;* globular, with finely granulated surface, about $\frac{1}{3000}$ inch in diameter; the addition of water causes a delicate cell-wall to rise up from the granular nucleus with which it was previously in contact. *Uses;* they are now commonly regarded as embryo blood disks, and are probably concerned in the assimilation of crude albumen into vitalized fibrine.

(*b*) RED DISCOID CELLS OF THE BLOOD, improperly called blood *globules.*—*Form*—Biconcave disks having a *circular* outline in man and the mammalia generally, except only the camel tribe, which have *elliptical* disks; as have also all the oviparous vertebrates. Average diameter in man $\frac{1}{3400}$ inch. Thickness, one-quarter the diameter. Tendency to run together in piles when drawn from the body. Effects of certain re-agents in altering their shape. When exposed to a liquid denser than serum, they give out a part of their fluid contents and become corrugated; if the liquid be less dense they absorb water and swell out into the form of biconvex lenses. *Structure;* colourless cell-wall, tolerable thick and tough; no nucleus in the blood disks of mammals. Other vertebrata have a distinct granular nucleus, identical with that of their chyle corpuscles, the colouring matter being superadded around the latter. Chemical composition, uses, vital properties, &c., to be noticed in connexion with the special physiology of the blood.

25. EPIDERMIS or CUTICLE. Definition; naked eye characters; physical properties. *Microscopic structure.* Next to the basement membrane we have a semifluid cytoblastema; then a stratum of *nuclei* or *cytoblasts*, then *epidermic cells* of primordial characters; then flattened cells, and lastly mere *scales*, the result of the desiccation of cells. *Uses;* Carpenter, *loc. cit.* § 224 to § 228.

26. PIGMENTARY BODY. *Definition;* a group of cells sometimes mingled with epidermic cells as in the skin of Africans; sometimes forming a distinct body, as in the pigmentum nigrum of the eye, which cells secrete colouring matter instead of horn. Anatomical and chemical character of *pigment granules.* Development of pigment cells. Carpenter §§ 229 and 230.

27. EPITHELIUM. *Definition.* The epidermis of mucous and serous membranes, whose constituent cells are never so completely flattened as to destroy their organization. *General characteristics*, those of nucleolo-nucleated cells. *Varieties.* (1) *Tessellated*, found on all serous and synovial surfaces, and on the endangium of blood-vessels and lymphatics, and on the smaller ramifications of gland ducts, except in the very follicular ends. (2) *Columnar* or *Cylindrical*, found on all mucous membranes, except where other varieties

are specified. (3) *Spheroidal*, found on the urinary tract from mouth of bladder up to the smaller uriniferous tubes, where it is displaced by the tessellated, on the mammary ducts, and in the terminal follicles of most glands. (4) *Scaly*, which is rather a soft cuticle than a true epithelium, found on the mucous membrane of the mouth, pharynx and œsophagus, terminating at the cardiac orifice of the stomach in a fringed border. *Ciliated epithelium*, is the name applied to any of the foregoing varieties when they are beset on their free side with *Cilia* (from "*Cilium*," an eyelash,) little hair-like vibratile processes from $\frac{1}{1300}$ to $\frac{1}{500}$ inch long, and immeasurably fine, found on the epithelium of respiratory tract, ventricles of the brain, and in the uterus and Fallopian tubes. Chemical composition: Uses. All the vegetative functions executed through the instrumentality of cells either epithelial or strictly analogous to these in their origin, as chylosis, hæmatosis, æration of the blood, nutrition, secretion and generation. Carpenter, *loc. cit.* § 231 to § 247.

D.—Tissues, composed in part of cells that are connected together as permanent constituents.

28. Such cells are connected either by a *general enveloping membrane*, or by an *intercellular cement*, the sacculi containing cells of adipose tissue exemplifying the former, and the hyaline matrix of cartilage the latter.

29. Adipose tissue. The structure containing the animal fat. *Distribution.* Sub-cutaneous, except on eyelids, pinna, scrotum and penis. Intermuscular; between the fasciculi of many muscles, around certain organs, as the eye, kidneys, base of the heart, &c. sub-serous, but never sub-mucous; in the medullary cavities and cancelli of bones—never in the lungs or in the cavity of the cranium. Fatty principles, but not adipose tissue, found in chyle and blood, either mechanically suspended or chemically dissolved. Found, likewise, intimately united with other ingredients, in many solids, as muscular fibre, and especially nervous matter, which has two peculiar fats; also *excreted* by sebaceous follicles of the skin. Finally, is formed as a morbid product, indicating *degeneration* of normal tissues, as fatty liver, &c., &c. For structure and development of adipose tissue, and its relations with areolar tissue; for chemical characters of oleine, margarine and stearine, physical properties and uses of fat, see Carpenter, loc. cit., § 257 to § 263, inclusive.

30. Simple, or cellular cartilage. *Definition.* The white gristle which incrusts the articular heads of bones, &c. *Distribution.* (1) Articular or incrusting cartilage. (2) Framework of larynx, trachea, bronchi, &c. (3) The unossified segments of the skeleton. These three are "*permanent cartilages*," although number (3) is closely related to (4.) *Temporary* cartilage, or car-

tilage of ossification. *Form.* Incrusting or articular cartilage of variable thickness, and thinning off at the edges, has a free, smooth surface, and another attached to the bone. *Colour.* Bluish-white, or pearly; translucent in thin slices. *Structure.* Apparently homogeneous to naked eye; non-articular varieties covered by perichondrium; articular, covered on free surface by synovial membrane, as proved before birth, by a layer of intervening vessels, which disappear after birth; these never have a perichondrium.

Microscopic character. Nucleolo-nucleated cells, imbedded in an apparently homogeneous hyaline matrix, with which the cell walls coalesce; cells multiply by binary division; hence, often seen in groups. By a very high power Dr. Leidy resolved the apparently homogeneous matrix into an exceedingly close tuft of very fine fibres. *Chemical characters, physical properties and uses*, see Carpenter, loc. cit., § 264 to § 273, inclusive.

31. Fibro-cartilage. *Definition.* Cartilage, of which the peculiar cells are imbedded in a net-work of white or yellow fibrous tissue in place of the hyaline matrix. *Distribution.* (1) Yellow fibro-cartilage found in the external ear, nose, epiglottis, tarsal cartilage of eyelids, &c. (2) Interarticular disks. (3) Articular marginal cartilages for deepening sockets. (4) Connecting or interosseous cartilages. (5) Cartilages lining the bony grooves in which tendons of muscles glide. For other characters, see Carpenter, loc. cit., § 269.

32. Bone. Two varieties of structure, the *spongy* or *cancellated*, and the *compact* or *ivory*. (1) *Cancellated*, how constructed; medullary membrane and oil. (2) *Compact structure*, very condensed, system of Haversian canals, &c. Three classes of bone distinguished by their form. (1) *Thick* or irregular, a mass of cancellated structure, covered by a thin shell of compact matter. (2) *Flat bones*, having two tables of a compact bone and an intermediate cancellated structure, presenting certain peculiarities, and called *diploe*. (3) *Long bones*, consisting of a shaft and two articular ends or *epiphyses*; medullary canal in the shaft; medullary membrane and fat; arrangement of blood-vessels. *Microscopic characters.* Elementary bony lamellæ, covered by delicate medullary membrane, whose vessels never enter the substance of the lamella. Osseous corpuscles or *lacunæ*, with radiating *canaliculi*. Interlacunar matrix of close fibres, with calcareous granules imbedded. Dimensions and other characters of lacunæ and canaliculi in different classes of vertebrates.

33. Mode in which the two varieties of bony structure are built up of the elementary lamellæ. (1) *Spongy or cancellated structure.* Compound lamellæ, formed of several layers of the elementary forms in close union, and covered with a highly vascular medullary membrane intersect to form cancelli, which are filled with reddish oil. (2) *Compact structure* formed of fasciculi of *ossicles*, closely packed together and arranged around the medul-

lary canal. An *ossicle*, a cylindrical rod of bone, pierced longitudinally by the canal of Havers, from $\frac{1}{2500}$ to $\frac{1}{2000}$ of an inch, or about $\frac{1}{500}$ as an average. The bony walls of this canal formed of several concentric cylinders of elementary lamellæ, fitting within each other with exceeding closeness, and each containing an immense number of lacunæ and canaliculi. Arrangement of these "*plasmatic tubes*," with reference to the Haversian canal, the exterior of the ossicle, and the intervening substance. Very minute dimensions of the canaliculi. A few lamellæ concentric with the medullary canal. Lateral communications between contiguous Haversian canals, so as to constitute a coarse net-work. Chemical composition, physical properties, uses, see Carpenter, § 288 to § 299.

34. DEVELOPMENT OF BONE. Three stages of osteo-genesis. (1) *Gelatinous stage*, consisting of primordial cells in a semi-fluid blastema. (2) *Cartilaginous*, representing the different temporary cartilages. A few flat bones are fibro-membranous in place of being cartilaginous. (3) *Ossific stage*, which may succeed either the membranous or the cartilaginous condition.

(*a*) *Intra-membranous ossification.* The flat bones forming the roof of the cranium, prior to ossification, exhibit "only a membranous layer, made up of *white* fibres and granular corpuscles, with a soft, amorphous or faintly granular uniting matter." The corpuscles are true cells, with an envelope and granular contents, most being two or three times larger than blood corpuscles. The fibres are calcified by impregnation with calcareous granules—a very vascular spot, (*punctum ossificationis*,) near the centre of the surface, indicating the point at which the process commences. Blood vessels, at first superficial, soon become inclosed by progressive deposits around them, and thus determine the formation of Haversian canals. The progressive extension of the ossific deposit in radiating spicula, with oblique connections, making a loose net-work, that afterwards becomes compact. The original granular corpuscles, it is probable, shoot out tortuous lines, and those organs resisting the deposit of calcareous matter, form the lacunæ and their radiating canaliculi.

(*b*) *Intra-cartilaginous ossification.* Arrangement of the cartilage cells near the *punctum ossificationis*. Penetration of blood-vessels to such point. First appearance of provisional bone (*without lacunæ, &c.*,) in form of a net-work, occupying the spaces between the columnar groups of cells. Subsequent enlargement of the areolæ of this temporary bone, from which the cartilage cells seem to disappear, and are replaced by a blastema, derived from the neighbouring vessels, and giving rise, by development, to a fibrous membrane and a new set of cells. These new structures then undergo ossification, in concentric layers, within the spaces bounded by the coarse temporary bone first formed. Formation of lacunæ and canaliculi from the cells of this ossifying fibrous membrane. Formation of Haversian canals. Bone, first spongy

and very vascular, may become very compact and almost non-vascular. Relation of the temporary cartilage to the permanent elements of bone. *Growth* and *regeneration* of bone. See Carpenter, § 300 to § 309, inclusive.

35. TEETH. *General conformation;* crown or body, neck, and root or fangs, alveolus, alveolo-dental periosteum. *Varieties of forms.* Incisors, canine, bicuspids, molars. *Dental formula of man. Structure.* Cavity of the pulp, canal extending through the fangs, dentine, enamel, crusta petrosa or cement. *Microscopic characters.* (1) Of the pulp. (2) Of dentine, which consists of microscopic tubules, opening by their large end into the cavity of the pulp, and radiating in lines perpendicular to the walls of this cavity towards the periphery of the tooth. The diameter of these tubular rods, at their large end, $\frac{1}{4500}$, with a bore of $\frac{1}{10000}$ inch; at the peripheral end, which exhibits numerous branches, they are immeasurably fine. Intertubular substance faintly granular. (3) *Enamel.* Prismatic, *solid* fibres, so closely packed that there is no intervening material; prisms four or six sided, adhering by one end to dentine, and free by the other; $\frac{1}{3600}$ inch in diameter. (4) *Cementum* has characters of true bone. *Chemical characters* of dentine and enamel, Carpenter, § 310 to § 319.

36. *Development of teeth.* Embracing, (1) an account of the formation of a tooth as a whole; (2) the formation of each of its structural constituents; and (3) the successive evolution of the different teeth in two sets—namely, the deciduous and the permanent set.

(*a*) *Development of the individual teeth as distinct and entire organs.* (1) *Papillary* stage. Papillæ, consisting of a mass of cells, inclosed by structureless membrane, and lodged in the *primitive dental groove.* Commences in seventh, and completed in tenth week of embryonic life, to be immediately succeeded by (2) the *follicular stage*, which is completed at the thirteenth week. (3) *Saccular* stage. Follicles closed by *opercula*, and become sacs. Structure of dental sac. External fibro-cellular layer; and internal highly vascular layer, lined with epithelium. *Cavity of reserve* between the operculum and the point at which the lips of the sac approach to cohere together. Development of future permanent teeth in these cavities, which are thus offsets from the sacs of the deciduous teeth. (4) *Eruptive stage.* Shortly before the closure of the follicles, the *papillæ* begin to assume forms more characteristic of teeth, and soon exhibit the exact shape of the crown of the coming teeth; henceforward called *pulps.* After a time, varying with the different teeth, the outer layer of the pulp becomes transformed and calcified into *dentine*, the process commencing on the cusps as an exceedingly thin shell, looking like an excretion moulded on the cusps. Successive enlargement in surface and thickness, the pulp becoming proportionally smaller in breadth and thickness, but being elongated towards the bottom of the

cavity. The incorporation of calcareous matter with this elongated fang, causes the tooth to be lifted towards the gum, which opposes less resistance than the bony surface at the bottom of the alveolus, until ultimately the crown of the tooth is said to *cut* its way through the sac and the gum, those tissues giving way, however, by progressive absorption and not by laceration.

(*b*) *Formation of each of the structural constituents of a tooth.* (1) *The pulp.* See Carpenter, § 310. (2) *Dentine.* Ib., § 313 and §314. (3) Enamel and cementum. Ib., § 320.

(*c*) *Successive evolution of the different teeth in two sets.* (1) Deciduous set, twenty in number. Dental formula. Incisors, $\frac{2}{2}$ $\frac{2}{2}$; canine, $\frac{1}{1}$ $\frac{1}{1}$; molars, $\frac{2}{2}$ $\frac{2}{2}$. Order of eruption. Middle incisors, lateral incisors, first molars, canine, second molars. Eruption commences at about seventh month after birth, and completed from eighteenth to thirty-sixth month. Order in which they are shed to be replaced by permanent teeth. The process of shedding is usually preceded by the eruption of the first permanent molar, *behind* the last deciduous molar, in the seventh year. Then the deciduous teeth drop in the following order, to be replaced in each case by a permanent tooth: Middle incisors, lateral incisors; first molar to be followed by first bicuspid of permanent set; second molar to be followed by second bicuspid; canine, which is the last of the deciduous set to fall out, occurring in the thirteenth year. Then appear second permanent molars, and finally, from sixteenth to thirtieth year, the third molars or *wisdom teeth.*

Development of permanent teeth in cavities of reserve, between the closed mouths of the sacs of deciduous teeth and their opercula. The *permanent molars*, however, lying beyond the range of deciduous teeth, form an exception. The first permanent molar, appearing before the shedding of any deciduous tooth, is developed at the back part of the *primitive dental groove.* Second molar developed in a cavity of reserve, an offshoot from the sac of the first, and the third from the second. Shifting of the position of the second, and especially of the third permanent molar, in the progress of the growth of the deciduous teeth and of the jaw bone. Possible consequences of the confinement of the wisdom teeth in the ramus of the jaw. Carpenter, § 321 to § 325, inclusive.

37. Hair.—In many respects analogous to teeth. Hair follicle—hair *bulb and pulp. Cortical* substance of a fibrous, horny texture. *Medullary* substance of a more distinctly cellular character. *Microscopic characters* of human hair—cortical layer, "a thin transparent horny film, composed of flattened cells or scales, arranged in an imbricated manner, their edges forming delicate lines upon the surface of the hair—within this a cylinder of fibrous texture, forming the principal part of the shaft, and only in the centre is there a distinctly cellular structure." Pigmentary matter between the fibres and *in* the cells, or sometimes equally diffused. *Development* of the several structures. Carpenter, §§ 329, 330.

E. Tissues composed of cells coalesced into tubes.

38. Dentine would be placed in this category by some histologists, but others deny the cellular origin of the dentinal tubules. Two classes of tubes having such origin, (1) those without any secondary deposit and serving as channels for the circulation of the nutritive juices, or else for conveying off the secretive fluids; and (2) those with secondary deposit, such deposit being organized elements executing vital acts, as muscular and nervous fibres.

Only the minute *capillary* vessels which are intermediate between the arteries and veins, and the smaller portion of glandular ducts, have their origin in the coalescence of cells laid end to end, the larger vascular and glandular tubes being formed of several layers of fibrous tissue, lined in the case of blood-vessels with a peculiar kind of serous membrane called *endangium*, and in the case of gland ducts with mucous membrane.

39. Arteries.—Definition. General form of a limited portion of an artery—of the whole arterial tree—of the trunk divested of its branches. Relation of the collective areas of the trunk and all its branches at any given distance from the heart, with those nearer to or farther from it. *Structure.* (1) *External fibro-areolar tunic*, penetrated by the nutrient *vasa vasorum.* (2) *Middle tunic* formed of *yellow elastic and pale unstriped muscular* fibres, most of which are circular but some longitudinal. They are arranged in layers, of which as many as forty have been counted in the aorta. The elastic fibres predominate in large arteries—the pale muscular in the small. (3) *Internal tunic*, or *arterial endangium*, consists of a layer of tessellated epithelium cells, resting on a peculiar, brittle, perforated or *fenestrated* membrane, which curls up when torn in shreds. The artery thus constructed is inclosed, with or without satellite veins, in a fibro-areolar *sheath*, to which it is united by a somewhat lax areolar tissue. Appearances of a living artery, color, pulsations. Patulous state of a dead artery emptied of its blood, provided it be of medium size or over. *Anatomical relations*—Satellite veins and nerves enclosed in a common sheath, *arterial anastomoses. Physical properties.*—Extensible, dilatable and elastic, owing these qualities mainly to the characters of the middle coat. Internal coat very brittle under the pressure of a sharp edge, such as a narrow thread. *Vital endowments*—power of tonic contractions.

40. Veins.—*Definition—general form and distribution.* Veins are similar to arteries in these respects, but are larger or more numerous, and less apt to retain their cylindrical form when emptied. Anastomoses more frequent. *Structure*, analogous to that of arteries; (1) external coat thin but tough; (2) middle coat has few if any yellow elastic fibres, the pale muscular fibres which also are sparse, being mixed with white fibrous tissue. Internal coat more

seroid, and less fragile than the arterial endangium, and is thrown into semi-lunar folds strengthened by included fibro-areolar tissue, so as to constitute valves which yield to the column of blood moving towards the heart, but prevents its reflux towards the capillaries. *Sensible appearances* of a living vein; bluish cylinder when filled with blood; no pulsations; easily compressible, collapsed when emptied. *Anatomical relations.*—Generally each artery lies between two satellite veins, except the larger arterial trunks which are accompanied by a single vein each. *Sub cutaneous* or *superficial veins* without accompanying arteries. Veins and arteries run apart from each other in the cranial cavity, vertebral canal, and some bones; *vasa vasorum* penetrate to the inner tunic. *Physical properties*—flexible, extensible and dilatable: less elastic and less brittle than arteries. *Vital endowments:* veins have less tenacity than arteries, but a superior plastic force.

41. Capillaries.—*Definition.* Test of their distinctive character: calibre not diminished by division, nor increased by union. Small arteries recognized in observations on the circulation of a living animal, by noting that the corpuscles move from trunks in *divergent* branches of a smaller size. In *veins* the currents *converge* from small tubes into larger ones. *Form of capillary system* in different tissues, a net-work of anastomosing tubes, the meshes being arranged conformably to the disposition of the component structural elements of the tissue or organ. Examples. Average diameter of a capillary blood-vessel $\frac{1}{3000}$ inch, but some are much smaller and others greatly larger. *Automatic* variations of calibre in the same vessels in a living animal. *Structure*—Capillaries under $\frac{1}{2400}$ inch have a simple homogeneous membrane, resulting from the coalescence of the walls of a number of cells. On each side they gradually assume additional elements, so as to pass into arteries and veins respectively. Around *articular cartilages* and in *erectile tissues* the minute arteries pour their blood into dilated pouches whence the veins arise. The same arrangement exists in the placental portion of the uterine walls in pregnancy. *Development* of *blood-vessels*, from nucleated cells sending out ray-like prolongations which coalesce and form a network of channels, &c., &c.

42. Muscular Tissues, *Definition;* the tissues endowed with vital contractility, and which, thereby, become the active instruments of the automatic movements of animals, are termed *muscular.* Two varieties; (a) those muscles which are subservient to the functions peculiar to animals, are characterized by a *striped* appearance of their ultimate fibres: (b) most of the muscles concerned in effecting those movements which are subservient to the functions of organic life, are characterized by pale, *unstriped* fibres.

43. *Striated variety of muscular tissue. Distribution;* all the voluntary muscles, those of respiration and expression, the heart, upper part of the gullet, and the muscles of the urethra. *General form and structure.* Body or venter, head, origin and insertion,

both of which are often *tendinous*. Fasciculi of red, soft fibres, mostly parallel to each other, though some may intersect as in the heart; areolar or fibrous sheath, interfascicular areolar matter, blood vessels and nerves and their relations to the proper muscular elements. *Microscopic characters.* Primitive or ultimate fibre *striated* with alternate light and dark spaces in a transverse direction; structure of fibre tubular, with delicate homogeneous wall, called *myolemma* or *sarcolemma*, with closely packed *fibrillæ* deposited in the tube, and from being originally cylindrical, becoming prismatic by mutual pressure in a fasciculus. *Structure of a fibril;* a chain of quadrangular bodies separated by pellucid spaces, in the middle of which a faint line can be perceived. The pellucid space also extends around the sides of the dark bodies. These appearances probably due to quadrangular cells, whose walls are pellucid, and whose cavities are filled with a highly refractive material. Explanation of the cross striæ. Lateral adhesion of the cells sometimes greater than longitudinal cohesion, and then the contents of a tubule separate by transverse cleavage into disks; average diameter of a tubule $\frac{1}{350}$ inch in male, and $\frac{1}{450}$ in female. Average diameter of fibril $\frac{1}{10000}$ inch. Carpenter, § 332 to § 336 inclusive.

44. UNSTRIPED VARIETY OF MUSCULAR TISSUE. *Distribution;* found in all the muscles of organic life, except the heart and upper part of the gullet. For its peculiar characters see Carpenter, §§ 337 and 338, from which it will be seen that the striated fibre is the perfect condition of the tissue, the CONTRACTILE CELLS of Kolliker and the pale unstriped nodose fibre representing early stages of its development. The contractile cells with long staff-like nuclei are often found unmixed in the smaller arteries, veins, and lymphatics, &c., &c.

45. *Chemical characters of muscular tissue.* The albumen and gelatine found in muscles probably belong exclusively to their nerves, vessels and interfascicular areolar tissue. *Fibrine*, the chief solid ingredient, is probably the sole solid organic ingredient in pure muscular fibre. The juice of muscle contains kreatine, kreatinine, inosinic acid, lactic acid, and certain salts, especially those of potash, (chloride and phosphate.) *Physical properties* of muscular tissue when relaxed; when vitally contracted. *Vital endowments:* plastic force, tonicity and rythmical contractility.

GENERAL ANATOMY OF THE NERVOUS SYSTEM.

46. Definition.—Varieties of nervous structure, (1) ganglionic or vesicular; (2) fibrous or white substance: fundamental office of each.

47. FIBROUS OR WHITE NERVOUS SUBSTANCE. *Distribution;* forms the trunk and branches of all nerves and also the white matter of the brain and spinal cord, where it comes into relation

with the ganglionic or vesicular substance. *Structure of nerves.* Neurilemma—fasciculi—ultimate nerve fibres, of which there are two kinds; (a) *tubular* or nerves of animal life, diameter $\frac{1}{4000}$ to $\frac{1}{2000}$ inch in nerves, but very minute, ($\frac{1}{14000}$ inch) in some parts of the brain; external homogeneous envelope, white matter of Schwann, and axis cylinder; more delicate tubes apt to become varicose under the least inequality of pressure. (b) *Gelatinous*, or nerves of organic life: flattened, soft and homogeneous, resembling unstriped muscular fibres; nucleated nodosities; diameter between $\frac{1}{6000}$ and $\frac{1}{4000}$ inch. See Carpenter, § 373 to § 375 inclusive.

48. GANGLIONIC, VESICULAR, OR CINERITIOUS SUBSTANCE.—*Distribution:* found on the surface of brain and cerebellum, and in circumscribed masses in the substance of these organs; as a continuous longitudinal mass in the centre of each half of the spinal cord; in the knotty enlargements called *ganglia* found on the posterior roots of spinal nerves, and on some other nerves; and finally at the peripheral expansion of some of the nerves of special sense. *Naked eye characters* as found (1) in brain and spinal cord; (2) in ganglionic knots on nerves. *Microscopic characters.* Ganglion vesicles of various shape and dimensions, disseminated through a granular matrix, and lying somewhat loosely in the midst of a minute plexus of blood-vessels. Carpenter, § 378 to § 380.

49. Anatomical relations of the two varieties of nerve structure, (a) In the brain and spinal cord. (1) Continuity of fibres with ray like prolongations of the cells. (2) cells included in a follicular dilatation of nerve tube. (3) Fibres merely passing among and around, possibly adhering to, but having no organic continuity with the ganglion cells.

(b) Relations of the peripheral ends of nerves with the structural elements of the tissue to which they are distributed, (1) in muscles: loops of nerve tubes around ultimate muscular fibres, or else a net work of the ultimate nerve tubes. (2) Of sensory nerves. In some cases, as in the retina, we find an expansion of vesicular matter, which by analogy is presumed to exist for all sensory nerves.

(c) Relation of nerve fibres within the trunk and branches of nerves. Mere juxtaposition and no anastomosis. *Nervous plexuses*, their structure and uses. Carpenter, §§ 376 and 377.

50. *Chemical* characters of nervous substance. Waste—development—regeneration—*vital properties, &c.* Ib. § 384 to § 390.

51. CLASSIFICATION OF THE HUMAN TISSUES FOUNDED ON THE CHARACTERS OF THEIR STRUCTURAL ELEMENTS.

I. MOLECULES OR GRANULES.
- (1) *Molecular base of chyle.*
- (2) Granular blastema.
- (3) Granular contents of pigmentary and other cells.

II. Nuclei, or Cytoblasts.	(4) The assimilating corpuscles of the "so-called *vascular glands*," such as the thymus, thyroid, spleen, &c. (5) The *free* nuclei in the gastric glands and juice. (6) Nucleated blastema, as on the surface of open wounds, &c. (7) Mammalian blood disk(?) according to T. W. Jones.
III. Simple, homogeneous membrane.	(8) Basement or primary membrane.
IV. Simple fibres.	(9) White fibrous tissue, as in tendons and ligaments. (10) Yellow fibrous tissue, as in the vocal cords, &c. (11) Areolar tissue, and the derms formed of it.
V. Nucleated cells, free and floating.	(12) The corpuscles of chyle and lymph, and the white cells of blood. (13) Red blood-disks of oviparous vertebrates.
VI. Cells imbedded in a vascular network, with or without a soft granular blastema.	(14) Absorbent cells imbedded in the substance of the intestinal villi, and engaged in chylosis. (15) Adipose cells. (16) Vesicular nervous structure.
VII. Independent cells, slightly held together by a mucous cement, and so arranged as to form membranous expansions.	(17) Epithelium and cuticle.
VIII. Cells with cavities distinct, but with walls coalesced by means of intercellular matter.	(18) Cartilage. (19) Fibro-cartilage.
IX. Sclerous elements, in which both the cell walls and the intercellular matrix have been hardened by horny or bony deposit.	(20) Hair and nails, consolidated with horny matter. (21) Bone. (22) Dentine, (23) Enamel, } with calcareous matter.
X. Cells transformed into tubes without secondary deposit.	(24) Capillary blood and lymph vessels.
XI. Cells converted into tubes with secondary deposit.	(25) Muscular tissue. (26) Fibrous nervous structure.
XII. Compound membranes — Fibrous structures, consisting of basement membrane and a layer of cells, with or without a derm beneath the membrane.	(27) Serous membrane, embracing, (a) Common serous m. (b) Synovial " " (c) Endangium. (28) Mucous membranes.

OUTLINES OF COMPARATIVE ANATOMY.

ON THE VALUE OF COMPARATIVE ANATOMY, AS SUPPLYING MOST OF THE DATA ON WHICH THE INDUCTIONS OF PHYSIOLOGY ARE BASED.

52. Complexity of the mechanism of man and other animals high in the zoological scale. Mutual dependence of the organs and correlation of functions. Action of each organ thus dependent on two sets of conditions; (1) those which *immediately* and *directly* influence it, and which may, therefore, be called *essential;* and (2)

those which primarily concern other organs, and only exert an *indirect* and *reflected* influence upon a given organ, for the reason that there must be a harmony of action throughout the system; these last conditions, though important, or even *necessary* are not *essential* in the sense employed, and may be called *concomitant* or *incidental* conditions. Examples: essential conditions of muscular contraction, contrasted with certain conditions which are incidental to the peculiar organization of man, in respect to the relation between muscular action and the functions of the heart and lungs. Simple observation of the vital acts in one species will not enable us to discriminate between the essential and incidental conditions, since both are necessary to the continuance of the acts, and, for the same reason, artificial experiments are precluded. But nature presents us with experiments already prepared, by exhibiting a chain of beings of continually decreasing complexity of organization, until we arrive at some in which any given function is executed in its simplest and most essential conditions. Ascending from this point, we notice the successive superadditions to each organ or apparatus of organs, and comparing these with the habits, sphere of life, and other peculiarities of the beings which exhibit them, we learn, by an easy induction, the uses or functions of the numerous superadditions which we find in most of the human organs, as compared with the simplest and most elementary state of the same organs in the lowest animals.

ON THE CHARACTERISTICS OF ORGANIZED STRUCTURES IN GENERAL.

53. Division of natural bodies into animals, vegetables, and minerals, the last comprising all bodies, whether solid, liquid, or gaseous, that do not belong to one or the other kingdom of living beings. Peculiarities of animals and vegetables, as contrasted with mineral matter. (1). *Peculiar structure*, called *organization*. An organism, a union of dissimilar *organs*, *i. e.* parts differing in structure and office, and yet all working towards some common end. So each organ is composed of different tissues, and each tissue of certain structural elements, most of which exhibit, under the microscope, a peculiar structure, and all of which are unlike mineral particles. Minerals are mere aggregations of *similar* particles, each having all the properties of all the rest. See *Carpenter, loc. cit.* §§ 4, 5, and 6, for apparent exceptions, &c. (2). *Form.* Organic forms contrasted with crystals, both as to appearance and as to the *forces* under which they are respectively developed. (3). *Size.* (4) *Intimate structure* and *consistence. Carpenter*, § 2 *to* § 10 *inclusive.* (5) *Chemical composition.* See Kirke and Paget's Human Physiology, chap. I. Notice especially the following points. (a) Small number of elements found in the organized kingdoms, not more than 16 or 17 out of the 62 found in the mineral kingdom, and the relatively large number (4, 5, or even

more) in most of the organic proximate compounds. (b) Their complex mode of union in forming these compounds, contrasted with the binary mode of union of the elements in inorganic compounds. (c) The large number of organic compounds formed out of a few ultimate elements. (d) Proneness to spontaneous decomposition dependent in part upon the complexity of composition, and favoured by the presence of nitrogen and water. (6) *The possession of peculiar forces*, which only exist while the organization is perfect. Mutilation of the organism not only arrests the action of the machine as a whole, but destroys the *capacity* for action in each part; whereas, in inorganic machines, the *properties* of the material are unaffected by the disturbance of its action from mutilation or other influences. Hence, our notion of organization implies not merely a mutual adaptation of dissimilar parts, but also the possession by each part of peculiar forces, which only exist while the entire organism is perfect.

ON THE DISTINCTIONS BETWEEN ANIMALS AND VEGETABLES.

54. Amplification and explanation of the aphorism of Linnæus, that "minerals grow; plants grow and live; animals grow, live, and feel." Thus the "vital powers of a plant are directed solely to the performance of the *formative* operations," and whatever movements it may exhibit, have reference to the same end, and originate in physico-vital forces that are entirely independent of consciousness. An animal possessing these same powers has also others that "are subservient to the operations of the *conscious mind*, so that *consciousness* and *spontaneity* are involved in many of its movements which thus originate in *psychical* causes." (*Carpenter.*) But signs of consciousness in lower animals are often equivocal. *Adaptive* movements following a received stimulation, do not require that the stimulus be *felt*, or that the movement be *voluntary*. Brief notice of *physico-reflex* acts. Besides there are certain organisms (*Protozoa*) admitted to be destitute of consciousness, and yet having more points of analogy in their structure and composition with animals than with plants, resembling the embryonic or transitional forms of higher animals. Hence, other grounds of distinction than the possession of consciousness are needed. (1) *Chemical characters.* Though vegetables have a proteinaceous compound entering into the composition of the *primordial utricle*, and form and store up other proteine compounds, yet they have their tissues mostly composed of *cellulose*, a ternary compound. All true animal tissues, on the other hand, are composed of azotized compounds, having four or more elements. (2) *Mode of alimentation.* Animals feed only on matter already organized. Plants alone have the power of generating organic compounds, by the union of their elements obtained from ammonia, carbonic acid, and water. Difficulty occasionally experienced in applying this as a

test. (3) The antagonistic *influences of animals and plant on the purity of the atmosphere.* Vegetables thus abstract from the atmosphere carbonic acid and ammonia, the chief sources of its impurity, and convert them into organized compounds, which are stored up in its tissues. These are taken in by animals, to be assimilated to their own structure; and, after fulfilling a temporary use as the instruments of vital actions, are, in those very acts, again disintegrated and returned to the atmosphere as carbonic acid, ammonia, and water, the identical impurities which the plant had originally removed, and which will be again removed by other plants. Thus, under the reciprocal actions of plants and animals, the "chemical and physiological balance of organic nature" is constantly maintained. (4) *Structure.* (a) Most animals require a *digestive* sac, in which to receive and melt down the organic compounds on which alone they feed. But this is an *adaptive* rather than an *essential* character, and may be wanting in low animal organisms. (b) *Nervo-muscular apparatus.* Some plants appear to possess a contractible tissue, which may be considered as the lowest form of a muscular apparatus; but where there are both nerves and contractile tissue, or even nerves alone, the organism can only be animal.

SUMMARY OF THE DISTINCTIONS BETWEEN ANIMALS AND VEGETABLES.

AN ANIMAL,	A VEGETABLE,
is an apparatus of COMBUSTION;	*is an apparatus of* REDUCTION;
possesses the faculty of locomotion;	is fixed;
Burns carbon, hydrogen, ammonium; Existing in sugar, starch, fat, albumen, fibrine, &c.	Reduces carbon, hydrogen. ammonium;
Exhales carbonic acid, water, oxide of ammonium, nitrogen;	Fixes carbonic acid, water, oxyde of ammonium, nitrogen;
Consumes oxygen, neutral azotized matters, fatty matters, amylaceous matters, sugars, gums;	Produces oxygen, neutral azotized matters, fatty matters, amylaceous matters, sugars, gums;
Produces heat, electricity;	Absorbs heat,
Restores its elements to the air or to the earth;	Abstracts electricity;
Transforms organized into mineral matters.	Derives its elements from the air or the earth;
	Transforms mineral into organic matter

(*Dumas and Boussaingault's Chemical and Physical Balance of Organic Nature.*)

animal

GENERAL VIEW OF THE ORGANIC KINGDOM.

55. Primary division of the animal kingdom into SUB-KINGDOMS or DEPARTMENTS, founded on the arrangement of their nervous system, which is an index of the general *powers* of animals, and consequently of the totality of their organization. Four different *types* or *patterns*, according to which the nervous system is arranged in the different animals possessing such an apparatus. A large group of organisms reckoned animal, and yet altogether destitute of nervous material. Hence, five sub-kingdoms, viz. :— VERTEBRATA, ARTICULATA, MOLLUSCA, RADIATA, and PROTOZOA.

56. VERTEBRATA, SPINI-CEREBRATA, OR MYELENCEPHALA (*myalos* "spinal marrow," and *encephalon*, "the brain.") Animals having the *vertebrate type* of nervous system, that is, with a cerebro-spinal axis, consisting of coalesced ganglia inclosed in a jointed vertebral column of bone or cartilage, and lying on the *dorsal* side of the nutritive apparatus. Brain, the anterior expanded part of this axis, consisting of the ganglia of special sense and certain superadded parts largely developed in the higher species. Generally five senses. Bilateral symmetry. Jaws always open in the line of the axis of the body. Red-blood disks. Never more than two pairs of special locomotive members. Ex. Fishes, reptiles, birds, beasts, &c.

57. ARTICULATA or HOMOGANGLIATA, with the *Homogangliate type* of nervous system; that is, a double *ventral* cord with ganglia at short intervals, generally a pair (right and left), coalesced on the middle line for each of the *jointed* annular segments of which the trunk is composed, and communicating anteriorly by nerves surrounding the gullet, with a pair of supraœsophageal ganglia usually coalesced into a bilobed mass connected with the nerves of special sensation and therefore regarded as a brain. In several of the higher articulates, the ganglia of several contiguous rings may coalesce longitudinally, and the resulting mass be drawn into one of the segments, as in certain insects, spiders, &c. But even though such coalescence were complete, the *sub-abdominal position* of the nervous axis would distinguish it from the spinal axis of vertebrates, which always lies on the *dorsal* side of the abdomen. Bilateral symmetry of body. Jaws open laterally. Blood generally colourless, and when coloured, as in the *annelida*, it is due to the liquor sanguinis, and not to the blood corpuscles. Locomotive limbs sometimes absent; when present they are never fewer than three pairs, and may be very numerous. Ex. worms, insects, crabs, &c.

58. MOLLUSCA or HETEROGANGLIATA. Animals possessing the *Hetero-gangliate type* of nervous system; that is, a nervous ring surrounding the gullet from which nerves radiate unsymmetrically to be connected with other *irregularly* scattered ganglia. No definite type as to form of body; consistence generally very soft, hence

named *molluscans*. Mucular skin or *mantle*. Many occupy calcareous *testæ* or shells, which may be *univalve*, *bivalve* or *multivalve*. Others constantly naked; many immovably fixed to rocks, &c.; others with imperfect locomotive members. Apparatus of nutrition very complete; animal powers relatively low. Ex. Oyster, snail, cuttle-fish, &c.

59. RADIATA, or CYCLO-NEURA, (*cyclos*, "a circle," and *neuron*, "nerve,") with a nervous system disposed with circular and radiate symmetry. A circular cord around the mouth, sending branches into each of the ray-like *lobes*, *arms*, or *tentacula*, given off from the body, or from around the mouth of the animal. According to CARPENTER and others, the nervous ring has gangliform enlargements opposite the base of each radiated appendage. But this is denied by OWEN, who considers the nervous system of the Radiata to be characterized by the absence of ganglia, and hence he terms them NEMATONEURA, that is, animals with a *filamentous nervous* system. Sometimes the whole body has the circular and radiate form, as in the Star-fish, but generally it is only the arrangement of the mouth and its tentacles, which conform to the type. In some of the *Radiata*, no nervous structure has yet been demonstrated, but their actions are such as to justify the inference that the elements of such a structure must exist in some form. These *Owen* proposes to erect into a special sub-kingdom under the name ACRITA, that is, animals with an *undiscernible* nervous system. Examples. Star-fish, (*nematoneurose*,) Zoophytes, (*Acrite*).

60. PROTOZOA, or ANEURA. Animals without any nervous system. Positive characters too variable to furnish grounds of distinction. Some are destitute of digestive apparatus, and are also motionless, their vital powers, like those of plants, being directed solely to the performance of the *formative* operations, but they are yet regarded as animals on account of their general analogies of structure. Having no common type of form, they have been called AMORPHOZOA, but as the same may be predicated of molluscans, the proposed term is less distinctive than the preferred one, PROTOZOA, (protos, "first," and zoon, "animal,") indicating the lowest stage of animal life.

SUB-DIVISIONS OF THE ANIMAL SUB-KINGDOMS.

61. The subordinate groups next in order to sub-kingdoms are termed CLASSES; which are divided into ORDERS; these into TRIBES; and FAMILIES; these into GENERA, and these into SPECIES, which last comprises all the individuals which may be supposed to have sprung from a common parentage. In presenting an outline of the anatomical characteristics of the principal classes of animals, it is better to begin with the lower and simpler forms, and to proceed in the ascending series.

A. Sub-kingdom. Protozoa.

I. Class—Polygastrica.

62. Infusorial. Microscopic, from $\frac{1}{24000}$ inch (*monas crepusculum*, in infusions of putrid flesh,) to $\frac{1}{45}$ inch (*Bursaria*). Under the name *Infusoria*, given by Leuwenhook, they were confounded with *Rotifera* of much higher organization. Appearance in their interior of a multitude of globular sacs, conceived by *Ehrenberg* to be multiple stomachs, and hence the class name. Ehrenberg's views contested by Meyen, Carpenter and others, who consider the sacs to be imperforate vesicles imbedded in a semi-fluid parenchma or *protoplasma*. They present an almost infinite variety of forms; a distinct mouth armed, in a few cases, with teeth; a few have a separate anal outlet. Surface in most species beset to a greater or less extent, with fine vibratile cilia, fulfilling a three-fold use. (1) By creating currents of water, they bring food within the reach of the animal. (2) They subserve respiration by constantly changing the water on the surface. (3) They propel the whole animal through the liquid medium. Skin tough, but very flexible, elastic and contractile. Some have *Setæ*, or stiff, inflexible hairs as organs of support; others have *uncini* or hooked limbs. They multiply by *fissiparous* division; sometimes by *gemmation*, and finally by *ovulation*, when the water in which they are contained, is about to dry up, &c. This class is not a *natural* one, being composed of heterogeneous species.

II. Class—Rhizopoda.

63. Protozoans of a very low grade of organization, most of which have this peculiarity, that their soft bodies are enclosed in calcareous or siliceous shells, with minute apertures, through which they project their *pseudopodia* (*false feet*,) which are long, thin, digitate prolongations of their soft body. These are used as means both of locomotion and alimentation. Being thus *root-like* in appearance and office, they give rise to the class name which means *root-footed*. Fossil remains of Rhizopoda of former epochs were called *Foraminifera*, from the apertures for the pseudopodia. Some of the shells are composite, each department containing a distinct animal, these are called *Polythalamia*, "many chambered." A few naked or *illoricated* Rhizopods, as the *Amoeba*, *Difflugia*, *&c.*, which project portions of their body so as extemporaneously to construct their pseudopodia; without oral orifice they wrap themselves around their food, and apparently secrete gastric juice by their skin. *Infusorial.*

III. Class—Porifera.

64. The various forms of the sponge tribe are arranged into a distinct class under the above designation, which indicates a conspicuous character common to them all, the perforation of their substance by very minute channels leading to a set of intercommunicating passages and excavations. Larger canals terminating in a set of larger orifices, the *oscula*, or vents. Two distinct parts in the fabric of a sponge: namely, the fibro-corneous skeleton, and the soft gelatinous flesh which clothes it. Structure of skeleton, which in a few rare species is altogether *siliceous* like spun glass, but generally the fibres are of a leathery nature, with only a few siliceous spicules scattered through it. Naked eye and microscopic characters of the semi-fluid gelatinous parenchyma, which is made up of an aggregation of cells $\frac{1}{1000}$ inch, "each of which has the characters of a distinct proteiform or amoebiform animalcule, having a certain power of spontaneous motion, obtaining and assimilating its own food, and altogether living *by* and *for* itself, except so far as it may contribute materials for the formation of the fibro-siliceous skeleton." Vital phenomena exhibited by sponges. Multiplication (1) by *ciliated gemmules*, or detached portions of the gelatinous flesh, which transport themselves to distant spots, where they lay the foundations of new sponges; and (2) by *capsules*, bodies of a larger size, and containing numerous globular bodies set free by the rupture of the capsule. These are probably true *ova*, and are developed towards winter, when the parent structure is about to die; a few fresh water species—all others marine.

B. Sub-kingdom Radiata.

I. Class—Polypifera or Zoophyta.

65. *Definition.*—Soft, inarticulate animals, mostly or wholly *Acrite*, consisting when single, of a body which forms the walls of a cylindroid cavity, the animal's stomach, closed at one end by a suctorial base, and terminated at the other by a circular disk perforated in its centre by a circular mouth, and giving origin around the latter to a series of radiating tentacula. It is, therefore, a mere self-moving stomach, with a single orifice for ingestion and egestion, fringed with sensitive and prehensile tentacula. Such structure is exemplified in the genera *Hydra* and *Actinia*, both of which are *single* and *free*. The former inhabiting fresh water, has its stomach excavated out of the general parenchyma,—the latter, a marine group, has a stomach with distinct walls suspended in an abdominal cavity. An immense majority of Zoophytes are *composite*, that is, a large number of individual polypi are connected

together by the fusion of the lower parts of their bodies, with a mass of gelatinous flesh common to the whole, called *Polypary*, the whole structure (*Polypary* and *Polypi*) being called a *Polypidom*. In a large majority of such genera the older parts of the polypary become *calcified*, when they are called *Lithophytes*, or consolidated with horny matter, when they are called *Keratophytes*. Sometimes the hard matter is deposited in the central axis, the fleshy matter bearing polypi being superficial, as in the *common Red Coral*. Sometimes the hard substance is external, forming tubes with the polypi emerging from the open ends (*terminal*) as the *Tubipora Musica*, (organ pipe coral,) or from orifices along their sides.

66. *Ordinal sub-division.* All the composite Zoophytes may be arranged in one of two groups, according as the individual polypi are *Hydraform* or *Actiniform*. (1.) Order HYDROIDA or Hydraform Polypi. Composite forms mostly arborescent and tubular, with the hard matter rather horny or pergamentaceous than calcareous. Multiplication by *gemmation*, *fission* and *ovulation*. (2) Order ACTINOIDA, also called ANTHOZOA, "animal flowers," resembling the *Helianthus*, *Anemone*, and such like composite flowers, both in form and beauty of coloration. Tentacula tubular, open at the free end, and communicating by the other with the interseptal compartments of the abdominal cavity, which also have minute orifices opening into the stomach, whence they receive water to distend their bodies. Genus *Actinia* has species six or eight inches in diameters; other genera very small. Hermaphrodite, with distinct testes and ovaries, on alternate septa of the abdominal cavity. Multiply on a compound mass by budding. Colonies multiplied by eggs, or by detached buds. To this order belong, besides numerous other families, the *Coralidæ*, *Madreporidæ* and *Madrephyllidæ*, which form the coral reefs and islands of the tropical seas.

With the exception of the genus Hydra, found in stagnant pools on aquatic plants, all the Zoophytes are marine.

II. Class—ACALEPHÆ or ARACHNODERMATA.

67. *Synonymes.*—Sea nettles—sting fish—jelly fish—sea blubbler. *Definition.* Radiate animals of a jelly like consistence, generally translucent, or even of a glassy transparency, with a large preponderance of fluid constituents, which drain away when the animal is taken out of its native element, the sea, leaving only a light cobweb texture weighing only a few grains, when the perfect animal weighed as many pounds. Some are splendidly phosphorescent; most *sting* and communicate this property to a limited quantity of water in which they lie for a short time, and to which they add a slimy secretion from their own bodies; great variety of forms; community of digestive, circulatory and respira-

tory passages; sexes separate. Hence generation oviparous. Singular phenomena of alternate generation.

68. *Ordinal division.* (1) *Pulmograda*, or discophorous Medusans. Disk shaped; mouth inferior and four lipped, or else in the form of minute pores at the end of long-depending root-like appendages (as in genus *Rhizostoma*); locomotion effected by rythmical contractions of the margin of the disk, resembling the alternate contractions and dilatations of lungs, hence the ordinal name. (2) *Ciliograda*, moving by means of vibratile cilia. (3) *Cirrhigrada*, moving by means of the action of curled tendrils or *cirrhi*. (4) *Physograda*, moving by reason of air vesicles, which they fill or empty at will. When distended, the animal rises by its buoyancy to the surface and is moved by the wind or tide, as *Physalia utriculus* (*Portuguese Man of War.*)

III. Class—Echinodermata (*spiny-skinned radiates*).

69. The class name, indicative of a very conspicuous feature in the best known species (star-fish, sea-urchin, &c.), resulting from the development of calcareous spines in their skin; but a great many animals now included in this class do not possess the character in question. Another character which is very common but likewise absent in some tribes, is the existence of *tubular, retractile cirrhi*, which serve as feet for some, and probably as respiratory organs for others. A still more common character, which is yet, however, wanting in a few, is the existence of *calcareous plates* (not the spines) in the substance of the skin, serving as a dermo-skeleton. In default of any single universal artificial character, the class is recognized by the ensemble of natural characters. Whereas the polypifera have no respiratory channels, and only a few families exhibit the first traces of lacunar passages for the circulation of nutritive juices, and the acalephæ have a community of digestive, circulatory, and respiratory channels, the higher radiates, designated by an inconstant artificial character (the prickly skin), really constitute a *natural group*, characterized by the possession of true blood-vessels with pulsatile walls at certain points, and of a respiratory apparatus, which in some is represented by the internal free surface of the peritoneum, and in others is a special localized apparatus. Nervous system distinctly radiate. Minute eyes found on the end of each ray of star-fish. Sexes distinct. Sexual organs multiplied. The number 5 and its multiples regnant in this class, as the number 4 is in the parallel class, *Arachnodumata*, or acalephæ. All are marine, and feed mostly on other animals.

70. *Ordinal division.* (1) Crinoidea or Pinnigrada, mostly fixed by a jointed calcareous stem to rocks, with the belly upwards. But the *Comatula*, now known to be the mature condition of the animal, which, when fixed in its early state, is called *Pen-*

tacrinus Europæus, is free, and moves by flapping the *pinnæ* or lateral barbs to its arms.

(2) OPHIURIDA or SPINIGRADA, like the Ophiurus, crawl by means of short stiff spines.

(3) ASTERIADA or CIRRHIGRADA, walk on solid surfaces by means of their suctorial, retractile cirrhi, projecting through the skin along the under surface of the rays. The stomach voluminous, and sends a pair of ramifying lobes into each of the five rays; which are, therefore, not tentacula or arms as are those of the two first orders, but merely lobes of the body. No anal outlet distinct from the mouth as in the other orders.

(4) ECHINADA or SPINI-CIRRHIGRADA, like the *echinus* (sea urchin), use both spines and tubular cirrhi as organs of locomotion. Their skeleton consists of ten meridian bands of calcareous plates, extending from oral to anal pole, and arranged in five pairs, consisting of *tubercular plates*, which bear long spines articulated with the tubercles by perfect ball-and-socket joints, with a *muscular* capsular ligament, alternating with five pairs of smaller bands the plates composing which are destitute of tubercles, but are perforated for the locomotive cirrhi, and are called *ambulacral plates*. Other plates are disposed around the mouth and anus which are terminal and opposite, the anus being uppermost. The echinus has a very curious dental apparatus called Aristotle's Lantern.

(5) CYSTIDEA. Fossil remains recently discovered. Seem to have become extinct before the pentacrinites were called into existence. Combine some of the distinctive characters of the *Crinoidea*, *Ophiurida*, *Asteriada*, and *Echinida*.

(6) HOLITHURIDA or CIRRHI-VERMIGRADA, like the *Holithuria*, have *cirrhi* in varying number, for different genera, and variously disposed; elongated bodies, and very muscular skin; hence vermigrade in water, and *cirrhigrade* on a solid surface; tentacula around the mouth; calcareous ring around the mouth, at the base of tentacula; respiratory tree opening into anal cloaca; genital apparatus with single outlet, &c., &c.

(7) SIPONCULIDA or VERMIGRADA. No cirrhi; no calcareous plates or spines; but internal organization strikingly similar to that of the Holithurida.

C. Sub-kingdom. MOLLUSCA or HETERO-GANGLIATA.

I. Class—BRYOZOA (*animal moss.*)

71. Microscopic, or very minute; generally found in composite masses like true Zoophytes, of which the polypary is either a creeping stem, or an aborescent trunk, or an irregular mass. Formerly confounded with true Zoophytes, as a sub-class termed *Ciliobrachiata*, their tentacles being fringed with vibratile cilia. Each individual composed of an external sac of which the outer

layer is either membranous, or horny, or rarely calcareous; arrangement of retractor muscles for drawing the mouth and tentacles into the tube and closing its orifice. Internal organization molluscan as respects digestive apparatus. They are the only mollusks without a distinct circulatory apparatus; ciliated tentacula probably organs of respiration as well as of alimentary ingestion; a *single nervous ganglion* between mouth and anus, which are near together, representing the lowest grade of *Heterogangliate type.* Propogation by attached buds growing on the polypary mass; colonies multiplied by ova, developed and fertilized by the same individual, the Bryozoans being hermaphrodite.

II. Class—Tunicata.

72. Body inclosed in a *tunic* or leathery bag quite distinct from the muscular mantle, and rather to be compared with the calcareous shells of the conchiferous species, being very tough, and sometimes having grains of sand agglutinated on its surface. Two orifices opposite to and corresponding with the oral and anal outlets of the true body of the animal. The oral opening in the tunic surrounded by short, radiating and ciliated tentacles, the anal separated from the true anus by a cloaca into which the genital passages also open. The tunic connected with the mantle at these orifices. Dilated Pharyux serving also as a respiratory sac, the surface between divided by regular folds and every where studded with respiratory cilia. Digestive apparatus similar to that of Bryozoa. A distinct circulatory apparatus consisting of a muscular heart with one cavity, alternately systemic and branchial, and two sets of vessels without valves, and each being alternately arterial and venous. Single nervous ganglion as in Bryozoa. Like the latter, many tunicata form composite masses. Two *orders.* (1) *Ascidiform*, embracing the single and the compound *Ascidians.* Both kinds fixed to rocks; the compound forms being developed from single individuals by continuous budding from a common stalk. (2) *Salpidæ*, also embracing single and compound forms, both of which are free, and move by means of currents of water discharged from their respiratory chambers. In the compound forms, the aggregated individuals have no organic continuity, but adhere pretty firmly by means of little suckers. Not identical with solitary individuals. A solitary salpa develops in its body an *internal stolon*, (having no true sexual organs,) from which buds sprout out, and are developed into an aggregated mass of which the separate individuals are of different sexes. Sometimes a whole chain consists of males, and others females. The product of true generation between the sexes is always a *single salpa* without sexual organs, but developing the internal stolon. Thus every alternate generation is a composite mass, and only at the intervening stages do the solitary individuals appear.

III. Class—Brachiopoda, or Palliobranchiata.

73. Bivalve acephalous mollusks, in whom the entire mantle serves as a branchial or respiratory organ, by having the branchial vessels distributed over it. In other respects the internal organization is sufficiently analogous to that of the following class to render it unnecessary to enter into details. The two long arms fringed with filaments that spring from either side of the mouth are neither prehensile nor locomotive instruments, but by means of the cilia clothing their surfaces, they create currents in the water for injestion and respiration.

IV. Class—Lamellibranchita.

74. Also bivalve and acephalous, and by reason of their importance among the acephalous classes, are frequently designated simply *Acephala*, as if this were a class peculiarity. The proper class name derived from a specialized respiratory apparatus in the form of four membranous lamallæ or leaves lying between the lobes of the mantle and fringing the body of the animal. Valves (separate pieces of the shell) connected by a hinge and an elastic ligament; closed by the action of one or two *adducter muscles*, pulling the valves into close contact and compressing the ligament. Valves lateral with hinge on the dorsal side. Many bivalves fixed, by adhesion of one or both valves to solid bodies, or by a tendinous cord, or mass of horny filaments, the *Byssus*. Others are free; some float; others leap or crawl by means of a muscular "*foot*" which, with others, is a boring instrument. Some have mantle open, (*Ostracea*). Others have the two lobes of the mantle more or less completely united, having in some cases simple apertures, and in others, syphonous tubes for respiration and defecation. Very large liver, as the dark part of the Oyster. Two-cavitied heart always systemic, and frequently perforated by the rectum. Most are *dioecious*, the genital parts lying back of the heart. A pair of œsophageal nervous ganglia communicating by cords *over* the gullet. Branchial ganglia. Pedal ganglia in those species which have a foot. One genus, Pecten, supposed to have ocelli around the margin of the mantle.

V. Class—Gasteropoda.

75. Mollusks whose instrument of locomotion is a muscular disk on the under surface of the belly. Very extensive class in which a few species are *naked*, but most have univalve testaceous shells, of which the typical form is a cone with expanded base, as in the Patella, but most frequently the axis is spirally disposed. For

structure and mode of growth of testaceous shells generally, see Carpenter, *loc. cit.* §§ 280 and 281.

Internal organization of Gasteropods considerably higher than that of any of the acephalous classes. Distinct head and organs of *special* sense. Ganglionic nervous matter *above* as well as *at the sides* of the gullet. Numerous orders mostly artificial. Order PULMONEA is however natural, exemplified in the genera *Helix* (*snail*) and *Limax* (*slug*) which have a respiratory *air* chamber with vascular walls. The members of this order are Hermaphrodite, with very complete organs of copulation; not capable of self-impregnation; most of the other orders are diœcious.

VI. Class—PTEROPODA.

76. Mollusks with a wing-like membranous expansion on each side of the neck, by means of which they swim through the water with great activity. "Should, perhaps, be regarded rather as an *aberrant* subdivision of the Gasteropoda, than as a distinct class," and have no special physiological importance or point of interest.

VII. Class—CEPHALOPODA.

77. Mollusks whose feet or locomotive appendages are attached to the head. These same appendages are also instruments of prehension, being armed with powerful *suckers*. In many, all the internal organs are collected into what may be called the head; so that the entire animal is a large head, from the under side of which there projects a thick circular membranous expansion, which divides into the long powerful arms that serve as feet when the animal crawls on a solid surface, with the mouth in the centre of the disk, downwards. Respiratory chamber in front of abdominal cavity, with syphonous outlet; the forcible discharge of water through which serves to propel the animal backwards. Approximation to vertebrates in the concentration of vesicular nervous matter above the gullet, and in having a rudimental cranium of cartilage. Two orders.—(1) TETRABRANCHIATA. *Nautilus*, the only known existing genus or species. (2) DIBRANCHIATA, exemplified by the genera *Octopus*, *Sepia*, *Argonauta*, *&c.*, *&c.*, which possess an *ink-bag*, not present in the nautilus. The general organization indicates a higher grade of animal existence than that of other molluscan orders. For arrangement of nervous ganglia see Carpenter, *loc. cit.* § 854.

D. Sub-kingdom. ARTICULATA OR HOMOGANGLIATA.

I. Class—ENTOZOA. (*Internal Parasites.*)

78. As the class name and the definition merely indicate the habitation of the species, it was a priori probable that, like the Infusoria, the group would prove not to be a natural one. Some Entozoa are Protozoans, some Radiates, and even the highest forms only indicate a *tendency* towards the articulate type, few, if any, ever attaining to the higher steps of the development. Yet there is some convenience in treating them as one group.

ORDINAL SUB-DIVISIONS OF THE CLASS.

79. *Order I.* CYSTICA, of which the simpler forms are mere animal cells, and therefore incontestably Protozoan. Best known genera and species found in the human being are (1) *Acephalocystis Endogena*, (*Hydatid*) a headless cyst, or mere organic cell of large dimensions, containing other and smaller ones, the product of endogenous development. (2) *Echinococus hominis*, or parent acephalocyst, filled with albuminoid liquid in which float little animalcules, consisting of a mere head with a circle of hooklets and four suckers. (3) *Cysticercus cellulosæ*, having a head and neck like the genus *Tænia* in the following order, and with an enlarged cyst for its body and *tail*, whence the generic name, which means a *cyst-like tail.* Another genus having some points of analogy with the two last, but not found in man, is (4) *Cœnurus*, which is an acephalocyst with a large number of tænia-like heads projecting off from its walls, and organically connected with them. The parent vesicle thus appears like *the common tail* of all these heads, whence the generic name. The *Cœnurus Cerebralis* is found in the brain of sheep and causes a fatal disorganization.

80. Order II. CESTOIDEA, which means *fillet-like.* Two species belonging to different but closely allied genera found in man; namely, (1) *Tænia solium*, having a head like that of *Cœnurus* or *Cysticercus*, which are quite probably abortive tænia with dropsical bodies. Articulate form—multiplication of genital apparatus, male and female, in each individual; opening on the margin of the flattened segments, on opposite sides of those that are contiguous. The history of the development of its innumerable ova is not ascertained. (2) *Bothrio-cephalus Latus*, distinguished by the two *longitudinal fossæ* on the head, and by the genital organs opening in the centre of the surface of each segment instead of on the margins.

81. *Order III.*—TREMATODA, which indicates as a characteristic the fact that the body has other openings besides that of the mouth and anus. This character is, however, in all probability,

illusory, and at all events it is unimportant. Still the order is retained on account of well-marked peculiarities of organization, which are likewise exemplified in certain *non-parasitic* aquatic worms the *Planariæ*. These accordingly are placed in this order. Mouth in the centre of a suctorial depression sometimes found on a projecting proboscis, at some distance from anterior end of the body. Stomach generally with ramifying lateral appendages. Distinct circulatory system consisting of but *few trunks*, themselves very small, and a minute net-work of capillaries. Organs of generation more localized than in the Cestoid order. Pair of ganglia anterior to the mouth, and indicating an arrangement somewhat intermediate between the molluscan and articulate types. In the lowest forms the cords from these ganglia *diverge*, as in molluscans. In the higher species they approximate towards the median line on the *ventral* aspect. The only genus known to infest the human tissues is the *Distoma* or *Fasciola*; as (1) *Fasciola Hepatica* (formerly called *Distoma Hepaticum*) or *Liver Fluke;* and (2) *Fasciola Lanceolata*, both species being found in the liver and gall bladder.

82. *Order IV.* Acanthocephala (*Prickly headed.*)—None found in man. *Echinorhynchus Gigas* of the hog, a most formidable parasite.

83. *Order V.* Nematoidea.—The entozoa of this order have a decidedly higher organization than the preceding. One distinctive trait is the existence of distinct walls to the alimentary passages, whereas in the preceding these passages seem to be mere excavations in the general parenchyma. Hence the latter have been designated as a distinct Radiate class Sterelmintha (solid worms,) while the Nematoid order has been elevated to a separate class called Cœlelmintha, (*Cavitary worms*). Other features of their organization exemplified by the *Ascaris Lumbricoides*, the common round worm. Sexes distinct, female being always larger, and having near its middle a circular constriction at one side of which is the vulva leading by a vaginal tube to the so called *uterus*, the dilated portion of the tube at the junction of the two ovarian tubes whose convolutions fill the hinder part of the body, except the axis, which is occupied by a straight intestinal tube. Male with an erectile intromittent spiculum projecting from the end of the tail. Lowest grade of articulate type of nervous system, namely, small supraœsophageal ganglion with ventral cord destitute of ganglia on it.

Table of Human Entozoa.

84. I. Sub-Class—Protelmintha.

(1) *Acephalocystis Endogena*,	Liver and peritoneal cavity.
(2) *Echinococus Hominis*,	Liver, spleen, omentum.
(3) *Cysticercus Cellulosæ*,	Areolar tissue between the fasciculi of muscles—eye—brain.

II. Sub-class—Sterelmintha.

(4) *Tænia Solium*,	(Tape worm)	Small intestines.
(5) *Bothriocephalus Latus*,		
(6) *Fasciola Hepatica*,	. . .	Liver, gall-bladder, &c.
(7) *Fasciola Lanceolata*,		

III. Sub-class—Cœlelmintha.

(8) *Trichina Spiralis*,	. .	Voluntary muscles.
(9) *Filaria Medinensis*,	(Guinea worm)	Sub-cutaneous areolar tissue.
(10) *Filaria Oculi humani*,	.	Crystalline lens.
(11) *Filaria Bronchialis*,	. . .	Bronchial glands.
(12) *Tricocephalus Dispar*,	. .	Caput coli.
(13) *Spiroptera Hominis*,	. . .	Urinary bladder.
(14) *Strongylus Gigas*,	. . .	Kidneys.
(15) *Ascaris Lumbricoides*,	. .	Intestinal canal.
(16) *Ascaris Vermicularis*,	. .	Rectum.

II. Class—Rotifera (*wheel animalcules.*)

85. Infusorial Articulates of microscopic dimensions, from $\frac{1}{12}$ to $\frac{1}{300}$ inch; characterized by the presence, in most species, of one or more fleshy lobes near the mouth fringed with vibratile cilia, having, when in action, the appearance of revolving wheels: when at rest the wheels are retracted as if the animal had swallowed them. Their use as means of ingestion. A few *loricated* species—skin exceedingly flexible and contractile with scarcely a perceptible trace of segmental division except in the tail, where there are several segments sliding upon one another in telescope fashion; curious dental apparatus at the bottom of the œsophagus; narrow stomach and straight intestinal tube dilating into a cloaca. Respiratory(?) syphon. Low development of Homogangliate type of nervous system. Ocelli in some species.

III. Class—Annelida, or more properly Annellata.

86. Vermiform Articulates, many of which are entirely apodal, while the others have only rudimentary *inarticulate* limbs; all breathe water except the members of one tribe, which breathe moist air; in most cases their blood is coloured; there is a much higher development of both vascular and nervous systems than we find in the highest entozoa which they resemble otherwise very closely. Except one order all are aquatic and most are marine. Ordinal sub-divisions. (1) *Dorsibranchiata* with dorsal branchial tufts generally coloured; very elongated segmental body, the segments being all alike except the terminal ones. Dorsal and ventral *oars* with a bundle of setæ on each side of both of the segments. (2) *Tubicola*

resemble the last, except that being enclosed in a tube, they have no locomotive oars, and the branchiæ are concentrated around the head. Hence have been called *Cephalobranchiata*. (3) *Terricola* includes the terrestrial and aquatic species. Thus the *Lumbricus*, common earth worm, lives in moist earth on land. The *Arenicola* which has dorsal branchiæ, but in other respects resembles the Lumbricus, lives in the sand under sea-water; organization lower than that of preceding orders, and resembles that of the Nematoid Entozoa. (4) *Suctoria*—as the *Hirudo medicinalis* (medicinal leech) whose organization resembles that of the Trematoid Entozoa; but yet they have a well developed homogangliate nervous system, the brain being connected with five pairs of optic nerves, and minute ganglia being developed on the ventral cord; three sharp saws in relation with the mouth for making their peculiar triradiate puncture.

IV. Class—Myriapoda.

87. Air breathing articulates, with elongated bodies divided into numerous similar segments, each of which except the terminal ones bears *one or two pairs* of *articulated* but generally feeble limbs. Integument more or less consolidated by *Chitine* into a somewhat firm dermo-skeleton. Respiratory apparatus *tracheal* like that of insects which they resemble in other features also of internal organization, except that in the lowest family, (*Julidæ*) the genital apparatus opens near the anterior part of the body. Two orders. (1) *Julidæ*, having for its typical genus the *Julus* (*millepede*) with very numerous segments, (40 to 80 in the perfect animal) each of which has *two* pairs of short and feeble legs. Segments cylindroid and dermo-skeleton not very hard. Development in early life consists mainly in multiplying the number of segments. (2) *Scolopendridæ* having the *Scolopendra* (*centipede*) as its typical genus with from 12 to 22 segments. The *Scutigera Longipes* (the common house centipede) belongs to this tribe. Genital apparatus opens behind as in insects.

V. Class—Insecta or Hexapoda.

88. Articulates with tracheal respiration and three pairs of legs attached to the three segments that immediately succeed the head and are consolidated into one mass called the Thorax. This in most perfect insects is separated from the head in front, and often from the abdomen behind, by a circular constriction which gives the animal the appearance of being nearly *cut through*, whence the class name. *External conformation of a typical insect.* Whole body covered with dermo-skeleton of greater or less firm-

ness, and of different colors in different species. Three principal regions—head, thorax and abdomen. Head having eyes, simple (ocelli) or compound, or both, the compound never being more than one pair—*antennæ* of various shapes—oral apparatus developed after one of two general types, either *mandibulate* or *suctorial*. (1) *Mandibulate*, vertical opening bounded on the sides by two pairs of jaws, mandibles and maxillæ; above by *labrum* and below by *labium* supporting the *lingua* or tongue. *Maxillary palpi*, sometimes two on each side. *Labial palpi*, never more than one pair. (2) *Haustellate* or suctorial mouth containing essentially the same elements, but adapted for suction by reason of the arrested development of some of them, and a very considerable modification of the form of others. The suctorial type is exhibited under three varieties, (a) as exemplified in Butterflies, the maxillæ being excessively prolonged and approximated so as to form a tube, which when not in use is coiled up spirally; other elements are rudimentary except the labium with its palpi.—(b) as exemplified in the mouth of bees, &c., where the maxillæ and the tongue are prolonged, the latter having feathery appendages in its sides, and being enclosed by the former, which are not joined together, but are capable of wide separation; mandibles and labrum well developed; (c) exemplified in the mouth of the *Cicada*, commonly but improperly called Locust. Maxillæ and mandibles form sharp lancets moving in an elongated *jointed* sheath; which opens by a groove on its upper or anterior side, in which the lancets lie when not in use. The mouth of flies is a sub-variety, in which the *unjointed proboscis* takes the place of the jointed beak of the Cicada. *Thorax* with three pieces, each bearing a pair of jointed legs having the several regions, Coxa, Femur, Tibia and Tarsus. In most insects two pairs of wings attached to mesothorax and metathorax, but never to prothorax. In beetles, &c., anterior pair hardened into *elytra* or wing covers, only the posterior being membranous and useful for flight. In one order hinder wings are wanting, and are replaced by a pair of *Halteres* or poisers. Some insects are *apterous*. *Abdomen*, may consist of nine segments, some of which are often metamorphosed into special organs, &c.; never has true legs, but may have appendages from the hinder segments for leaping, or as instruments for stinging, seizing objects or laying eggs (ovipositors.) Typical number of segments 13 or sometimes 14, one or two for head, three for thorax, and nine for abdomen. In the early or *larva* state all are distinct and similar, except that the head pieces bear the oral apparatus and eyes, and in most cases the thoracic pieces bear rudimental legs. At this stage also, in some species and families, the abdominal segments bear false legs which ultimately disappear.

89. *Internal organization of Insects.* Alimentary canal with usual divisions, and generally three or more pairs of tubular secreting organs connected with it, pretty well proven to be salivary, biliary and urinary; cloaca and anal outlet. *Dorsal vessel* or heart,

elongated, segmental with valves between segments, and bilateral symmetry; vessels frequently mere laeunar passages. *Respiratory* apparatus tracheal, that is, a system of tubes kept open by spirally disposed rigid and elastic fibres placed between inner and outer coats of the tube. They open on sides of the abdomen by *stigmata* or *spiracles*, and ramify all through the system. Hence no need of a pulmonary circulation in insects. Nervous system homogangliate with a remarkable tendency to a concentration of many of the ventral ganglia into one thoracic mass. Large bilobed brain in correspondence with the large development of important sensory organs, namely, eyes, antennæ and palpi. Respiratory ganglia lie between the locomotive ganglia; also stomato-gastric ganglia in front and also behind the cerebral ganglia. See Carpenter, *loc. cit.* §§ 862 and 863. *Reproduction* by ova fertilized during sexual union, all perfect insects being *diœcious*. Alternate generation exhibited by the *Aphides*, where for several generations the individuals are like the solitary *salpæ*, destitute of generative organs, and produce internal stolons from which young ones proceed by gemmation. They thus appear to be viviparous. At the tenth generation perfect winged males and females are produced, and these form fertile ova in the usual way, to survive the winter.

90. *Metamorphosis of Insects.* With the exception of the apterous orders, whose young resemble the mature animals, insects are hatched in a form more or less dissimilar to that of the parents, and pass through two intermediate stages before they acquire the characters of the perfect being. In the first stage after emerging from the egg, it is called a *Larva*, which is always wingless, and has only short hooked legs, or none at all; while the body is worm-shaped, the segments being nearly similar, and the integuments mostly soft. Living a variable time in this state, it becomes a *Pupa*, generally confined like *an infant swathed in bands*, but sometimes as active as the larva and recognized by rudimental wings enclosed in a wing case. After a variable time the *Pupa* changes into the Imago or perfect winged insect. Several kinds of pupa, as (a) *nympha* with separate cases for each of the limbs which are thus unconfined, though pressed against the body. (b) *Obtected pupa* in which there is a pupa case binding the limbs to the body, the forms, however, of the members being marked in relief on the outer surface. (c) *Coarctate pupa*, where the pupa case is the dried skin of the larva without any markings on the surface. Sometimes a larva spins a *cocoon* before the pupa case is formed and moulded over its body. Insect eggs. Varieties of larvæ. (1) Those of the Orthoptera, Hemiptera and some Neuroptera, resemble the imago, except in wanting wings; pupa active, and has rudimental wings; larva and pupa often aquatic. *Cicada Septendecim* lives as larva and pupa deep in the ground seventeen years. (2) Larvæ of most Coleoptera and some Neuroptera are termed *Grubs*; have elongated bodies, with three pairs of short thoracic legs, and sometimes, though rarely, a terminal pro-leg. Head

generally firmer than other segments; sometimes dorsal shields all along the body, or for some distance from the head. Pupæ of the variety called Nympha. (3) Larvæ of the Lepidoptera and one family of Hymenoptera, namely, the Tenthredinæ (saw-flies) are of the kind called *Caterpillars*, which have besides the six thoracic legs, several pairs of abdominal false legs. Pupæ obtected and often inclosed in a cocoon. (4) Larvæ of all the Hymenoptera except the saw-flies are footless, but have a mandibulate mouth by which they are distinguished from (5) the larvæ of the Diptera, which are footless *maggots* with a suctorial mouth. Some of these have false abdominal pro-legs. In the footless larvæ of Diptera and Hymenoptera there are apparently 14 segments, the two first forming the head. In all others there seem to be but thirteen, the first forming the head alone; antennæ slightly or not at all developed; eyes always simple when present at all, being entirely absent in the apodal larvæ of the Hymenoptera.

91. *Enumeration of the ordinal sub-divisions.* (1) *Coleoptera*, anterior wings *elytral* and meeting in a straight line on the top of the back; the true filmy wings folded *transversely* when at rest; metamorphosis complete; Larvæ generally with six true legs, and sometimes with a terminal pro-leg; more rarely without any legs at all. Pupa, with wings and legs unconfined, called nympha.

(2) *Orthoptera;* anterior wings rather thick, coriaceous and opake, overlapping a little on the back; posterior wings larger, thinner, partly coriaceous and partly membranous, folded *longitudinally* like a fan, whence the ordinal name; transformation only partial, larva and pupa being like Imago.

(3) *Neuroptera;* 4 wings minutely reticulated; posterior largest; head large; eyes projecting; metamorphosis complete for some; partial for others.

(4) *Hymenoptera;* wings four, membranous, with large arcolar reticulations; *posterior smaller than anterior;* antennæ longer than the head; eyes large; ocelli three; mandibles generally dentated; maxillæ largely developed and inclosing a proboscis formed by the labium and tongue; female armed with a borer, or a sting; metamorphosis complete; pupa of the nympha variety.

(5) *Strepsiptera*; 4 wings; anterior very minute and twisted, projecting from the meso-thorax like little scales; posterior large and fan-like; metamorphosis complete.

(6) *Lepidoptera*; 4 wings covered with a coloured dust which consists of microscopic scales; mouth haustellate; labial palpi large and hairy; metamorphosis complete; larva a caterpillar with six true and several pair of false legs; pupa obtected.

(7) *Hemiptera* or *Heteroptera;* 4 wings; anterior partly leathery and decussating at apex; *scutellum* very large; mouth haustellate with jointed beak; three ocelli; metamorphosis partial, larva and pupa like Imago, &c.

(8) *Homoptera;* 4 wings; anterior either entirely coriaceous or

entirely membranous; not decussating; prothorax short; metamorphosis partial.

(9) *Diptera;* two wings, membranous; halteres; haustellate mouth with unjointed proboscis; metamorphosis complete; *pupa coarctate*, inclosed in dried skin of larva, but with wings and legs free within this species of cocoon; larva maggot-like, with breathing holes on hinder part of the body.

(10) *Aphaniptera;* wings none or rudimental; body oval, compressed; eyes simple; thighs strong; hind-legs longest; metamorphosis complete; larvæ footless; pupa inclosed in a cocoon; ex. *Pulex irritans* (*Flea*).

(11) *Parasita;* without wings; mouth mandibulate in some species; suctorial in others; *no appendages to tail;* external parasite; no metamorphosis.

(12) *Thysanoura;* without wings; mouth mandibulate; abdomen terminating in a bushy appendage for leaping; no metamorphosis.

VI. Class—Arachnida.

92. Air breathing Articulates whose head and thorax are consolidated into one piece named cephalo-thorax, and bearing *four* pairs of articulated legs. Abdomen either globose or elongated, but always, as in insects, destitute of locomotive appendages; never winged; antennæ always wanting; but the maxillary palpi are very largely developed, so as in many instances to resemble a fifth pair of legs, terminated by *chelæ* or pincers, like those of a lobster; consistence of dermo-skeleton variable, but less frequently hard than among insects; mouth mandibulate for biting, but the opening is exceedingly small, and imbibes the juice of its victim, which is compressed by the action of the maxillæ. Ordinal subdivisions. (1) *Pulmonaria*, breathing by means of pulmonary sacs, and having from 6 to 12 ocelli. (2) *Trachearia*; breathing by means of tracheal tubes, like insects, and never having more than *four* ocelli. The pulmonary order subdivided into two tribes, (a) the *Araneidæ* or Spiders, and (b) the *Scorpionidæ* or *Pedipalpi*, in whom the maxillary palpi are enormously developed into large feet, terminated by chelæ. They have both the cephalothorax and the caudiform abdomen elongated and marked off with segmental divisions, the last segment having a perforated hook-shaped sting, the canal in which communicates with a poison bag. Great concentration of ganglionic matter within the cephalothorax of the Arancidæ; ganglia in each segment of the Scorpionidæ. The Tracheary order includes with other tribes that of the *Acaridæ* (*Mites*), of which two species of different genera, are external parasites of man, namely, *Sarcoptes Scabiei* (Itch insect,) and *Demodex Folliculorum*.

VII. Class—Crustacea.

93. This class includes all the water-breathing Articulates which have articulated legs. As a group, it is, therefore, parallel to all the classes of air-breathing Articulates, and in its lowest forms seems scarcely higher than the Annelidans, while it includes others which rank as high as the most perfect insect or Arachnidan. It has also some very *aberrant* forms, that is, forms which in the aggregate of their characters, depart widely from the aggregate of the characters belonging to the common and typical species of their class, although they retain the fundamental peculiarity on which the group is founded. Generally, such aberrant forms serve to connect the group to which they truly belong, to others which they resemble in certain particulars more or less striking or important, and are said to be *osculant* in their relation to the two groups which they thus connect. Thus the class *Crustacea* includes an immense variety of forms of different grades of organization, and hence a natural classification into orders is not very easily made out. *Four sub-classes.* (1) *Crustacea Ordinaria*, or those which have the typical characters with less decided deviations. (2). *Crustacea Entomostraca*, comprising all the minute forms, many of which have a carapace arranged like a bivalve shell, that inhabit stagnant waters, including, therefore, the Branchiopodans as well as the proper Entomostracous orders. (3) *Crustacea Suctoria*, mostly external parasites, and formerly considered a distinct class called Epizoa. They exhibit very grotesque shapes, and are *osculant* between the Crustacea proper and the Entozoa. Their crustacean nature is revealed by their great resemblance in their early larval stage, to the larvæ of Entomostracans. Examples are *Lernaca* and *Actheres*, both of which are fixed to the cutaneous or mucous surfaces of animals in their mature state, but as larvæ they are free and locomotive.

(4) *Crustacea Cirrhopoda* or Barnacles; which are exceedingly aberrant and osculate towards the molluscan sub-kingdom.

94. The ordinary crustaceans are subdivided into several orders, of which only the *Decapoda* needs be mentioned here, itself subdivided into three sections, (a) *Macroura*, (long tailed) as the *Lobster*, &c., (b) *Brachyoura* (short tailed) as the *Crab* and (c) *Anomoura*, having tails of an intermediate character, and more irregular as to shape, as the *Paguridæ* or *Hermit-crabs*. The highest grade of crustacean organization exemplified in the structure of a crab. Head, thorax and abdomen, the two former covered by *carapace*, or dorsal shield resulting from the enormous development of the dorsal scale of one of the pieces of which the head is originally composed. Each region has originally seven pieces, although in most species the number may be considerably diminished by arrest of development *within the egg* before all the

pieces are evolved, or by subsequent consolidation of separate pieces. Crustaceous dermo-skeleton partly of chitine, but largely formed of carbonate of lime. Traces of originally separate segments of the head in (1) pedunculated eyes; (2) short antennæ; (3) long antennæ; (4) mandibles; (5) (6) and (7th) the three upper pairs of maxillæ or foot-jaws. The two first thoracic pieces have also foot-jaws, of which the last are long and cover in all the rest. Thus the animal may be said to have six pairs of jaws, namely, the mandibles and five pairs of maxillæ, of which the three last pairs, namely, the last cephalic and the two anterior thoracic pieces, are really ambulatory in some of the crustacean orders. Abdominal appendages rudimentary in Decapods, but well developed in some orders; gastric teeth; lobulated liver; *systemic* dorsal heart sending forth a mixed blood, since a part of the returning venous channels proceed directly to the heart, another portion proceeding to the gills, lodged in branchial chambers under the sides of the carapace, receiving water from behind and, pressed upon by a *flabellum*, expelling it in front near the base of the foot-jaws. Right and left generative organs distinct and opening by separate orifices in the first joint of the third pair of thoracic limbs in the female. In the male the vasa deferentia open on the first or second pairs of abdominal appendages, which are probably intromittent organs. Lateral hermaphrodism not uncommon.

95. As stated above, the sub-class Cirrhopoda are osculant with molluscans. Indeed, Cuvier regarded them as molluscans. The points of analogy are their soft consistence, their muscular mantle, their multivalve testa and the absence of a head, being destitute of organs of special sensation in their mature state. But the essentially articulate character of a homo-gangliate nervous system is retained, while the mouth has lateral jaws, and the symmetrical body is faintly marked off into six segments, each having a pair of three-jointed fleshy legs, and each of these terminating in two elongated, curled, jointed, ciliated cirrhi, the alternate projection and retraction of which serves to create currents of water towards the animal's mouth for food, and towards the respiratory organs for aeration of the blood. Two orders, (1) *Pedunculata* or *Lepadidæ* (Barnacles) characterized by the existence of a fleshy muscular pedicle, by which the animal is attached to floating timbers, sea-weed, &c. Body enclosed in a shell of five valves, two pairs and one odd dorsal piece; cirrhi very long. (2) *Sessilia* or *Balanoidea*, as the Balanus (Acorn-shell); no pedicle; valves 12 in number, and triangular in shape, six with their bases, and six with their apices implanted perpendicularly on the rocks to which they are soldered. These pieces alternate and constitute a hollow cone with a truncated apex, in which the animal lodges, covered at will by a multivalve operculum.

E. Sub-kingdom—Vertebrata or Myelencephala.

96. Two features common to the higher forms of Invertebrate nervous system, in one of which we note a contrast, and in the other a point of approximation to the vertebrate type; (1) "the want of any proper or defined abode in the body of the animal," being "seldom better cared for or protected than any of the other soft parts;" (2) the coincidence of a higher grade of organization with a concentration of ganglionic nervous matter by the coalescence of ganglia separate in lower species. In molluscans is manifested a tendency to concentration around the gullet, and in articulates to a coalescence in a longitudinal direction along the ventral cord. In vertebrates we recognize the traits of a higher type of organization in the existence of a *continuous cord* of *cineritious* nervous matter, or coalesced ganglia located in a *special cylindrical cavity* resting on a jointed flexible column—the vertebral column. Nervous matter swells out at certain points, especially in front at the brain. Five special modifications of sensibility. Special locomotive appendages never more than two pairs; the pectoral or anterior pair, and the abdominal, pelvic or posterior pair. Body symmetrical except in a few aberrant species. The rapid disintegration, which is a condition of the functional action of the nervous and muscular system, requires a corresponding energy in the functions of repair, and hence a well developed nutritive apparatus. Spleen, pancreas and portal circulation superadded to the nutritive apparatus of the higher Invertebrates. Heart always present and muscular; aerating medium, whether air or water, introduced by the mouth; sexes always distinct. Parental instinct; dependence of offspring on parental cares and protection.

97. *Characteristics of the vertebrate skeleton.*—Definition of a skeleton founded on its subserviency to a threefold use; (1) constitutes columns of support; (2) it forms levers which are acted on by the muscles so as to be the passive instruments of the movements of the body; (3) forms the walls of protective cavities, in which delicate organs are secured from harm. In most of the Invertebrates these uses are fulfilled by the skin, rendered firm by consolidation with *chitine*, or with *carbonate of lime*, and hence called a dermo or exo-skeleton, while the vertebrate skeleton is always internal, and hence called endo-skeleton. The former is an extra vascular epidermic excretion, undergoing no vital changes; the latter a highly vascular *fibrous* tissue, partly consolidated by phosphate of lime, but leaving lacunar passages for the transmission of nutritive plasma, even through the densest portions.

98. A vertebate skeleton, a longitudinal series of annular bony segments, called vertebræ, all originally similar, but some of which undergo special modifications of form in adaptation to special uses. In many invertebrates similar changes take place after the

birth of the animal, and are therefore very easily substantiated, as the singular metamorphosis of Insects and Crustaceans. In the higher vertebrates, most of the morphological changes are accomplished in the uterus or the egg, while the embryo is very immature, and when it is not easy to recognize the anatomical characters of its subordinate parts. But the series of animals in the whole vertebrate group is parallel to the series of embryonic forms of the higher species, and is more easily traced in its several grades. The lower forms generally exhibit the typical characters of the skeleton with the smallest amount of *adaptive modifications*, whereas in the higher these modifications are often so great that we scarcely recognize the original pattern until we contemplate the transitional grades. Two principles govern the morphological tendencies of organized structures: (1) the principle of conformity to type or an ideal pattern; (2) the teleological principle, or the principle according to which forms are adapted to the use which they are required to fulfil. The former also called principle of *Homology*. Two organs are homologous when they are constructed after the same pattern, *however much they may differ in shape*, and for howsoever diverse uses they may be intended and adapted. Upper limbs or arms of man, forelegs of the horse or ox, the burrowing arms of the mole, the wings of the bat, and those of a true bird, the paddle-like fins of a whale, and the pectoral fins of a true fish, are all *homologous*, being constructed on the same pattern, though unlike in outward shape and fitted for very diverse uses. They are, in fact, the same organ, modified so as to meet the requirements of the principle of adaptation to specific uses. Two modes of recognizing homological affinities when these are masked by teleological adaptations. (1) By the discovery of a series of transitional forms connecting by an easy gradation any modification, however extreme, with the more typical forms. Two such series, one exhibiting the *successional* changes in the embryo of any given species, especially in the higher classes, the other exhibiting the various gradations of forms in the whole group of vertebrated animals; the latter series being the permanent reproductions of the former, and the two serving to illustrate each other. (2) The original type is further disclosed, under any mask, by the discovery of its structural elements, themselves recognized as such by their arrangement in relation to one another and as parts of the whole.

99. A vertebra is any one of the segments, the longitudinal repetition of which gives rise to a vertebrate skeleton. It includes, in addition to the parts which are known in the ordinary terminology of human anatomy under that name, a ventral arch for the protection of the nutritive apparatus, called *Hæmal Arch*. Thus a complete vertebra consists of two arches abutting upon a common *centrum*, the so-called body of the vertebra, one dorsal inclosing the nervous centres, and called neural arch or ring, and one ventral inclosing the organs of Hæmatosis, the Hæmal Arch. The

latter has on the right and left, diverging appendages, of which those for two of the segments are expanded into well developed, articulated locomotive or prehensile extremities. Constituents of a complete vertebra: (1) centrum common to both arches; the neural arch is completed by (2), two *neurapophyses*, and (3) a *neural spine* sometimes divided along the middle line. The hæmal arch is completed by (4), *hæmapophyses*, and (5) *hæmal spine*. When the hæmal arch is large, *as it generally is*, another element is intercalated between the centrum and hæmapophysis on each side; namely, the *pleurapophysis* of which the ribs furnish a striking example. Transverse processes anterior and posterior, (Parapophyses and Diapophyses,) are external growths or processes for muscular attachment, and are not necessary constituents of either arch, although under particular circumstances they may form a part of them. Structure of the diverging columns when fully developed into pectoral and abdominal limbs.

100. Definition and characteristic of the Archetype Vertebrate Skeleton. Number of *complete vertebral segments* determined by the number of distinct segments in the cerebro-spinal axis, which is indicated by the number of distinct sensori-volitional nerves emerging from the cord. They pass out from the vertebral case either between the neurapophyses of contiguous vertebræ, (Intervertebral foramina,) or by perforating the separate neurapophyses. These anatomical relations serve to indicate the distinctness of vertebræ after two or more have been consolidated together, as in the Sacrum. The four anterior neurapophyses of the vertebrate skeleton give issue to nerves, the terminal modifications of which constitute the organs of special sense, namely, (1) Olfactory, (2) Optic, (3) Gustatory, and (4) Acoustic. *Upon* the ganglionic centres of these nerves other ganglionic masses are developed in the higher classes, ultimately acquiring such a preponderance as to cover over and bury the more general ganglia of sensation. The cerebral organs of the intellectual and moral faculties thus superadded to the sensorial ganglia do not occasion the development of new vertebræ, but give rise to an enormous expansion and other modifications of the four constant cranial vertebræ. Incontestible evidences of the vertebral nature of the cranium furnished by the two tests already laid down, (1) comparison of the transitional forms; (2) the recognition in each of the four segments of the cranium of all the elements of a true vertebra. These cranial vertebræ are, (1) *occipital* with hæmal or scapular arch displaced in all vertebrates except the Osseous fishes—the vertebra of audition; (2) the *Parietal* or *Gustative vertebra* with the Hyoid apparatus for its hæmal arch; (3) Frontal or Optic vertebra with lower jaw for the hæmal arch, and (4) Nasal or Olfactory vertebra with the upper jaw for the hæmal arch. The parts which complete these vertebræ comprise all the bones of the cranium and face, except the *Petrosal*, the *Ethmoidal*, (lateral masses of the Ethmoid,) Inferior Turbinated and Os Unguis, which are parts of

a splanchno-skelcton. In most vertebrated animals we find a certain number of hard pieces, generally bony, sometimes cartilaginous, or fibrous, or horny, which do not properly belong to the endo-skeleton, although in a few cases some of them may, for certain adaptations, be intercalated among the proper segments of the endo-skeleton. Some being more or less closely connected with the external skin, seem to be detached pieces of an incomplete dermo-skeleton, while others being *integral constituents* of certain important organs or viscera rather than simple protectors of such viscera, are termed *Splanchno-skeleton.* The principal pieces of the splanchno-skeleton in higher vertebrates are, (1) Petrosal bone or Ear capsule; (2) Sclerotic capsule or Eye capsule; (3) Ethmo-turbinal or nose capsule; (4) Dental apparatus; (5) Vocal and bronchial apparatus, &c. The dermo-skeleton is represented by hair, feathers, scales, bony scutes, &c. In man the os unguis seems to be the only trace of an ossific portion of dermo-skeleton. It is only in the higher mammalia, whose large brain required an expanded cranium, that the pieces of splanchno-skeleton (Petrosal and Ethmoidal,) are intercalated among the cranial parietes. Brief notice of the several regions of trunk vertebræ, as (a) cervical region; (b) thoracic region; (c) lumbar region; (d) sacral region; (e) caudal or coccygeal region.

I. Class—Pisces.

101. Cold-blooded vertebrates, breathing water by means of gills, to which the whole of the blood is sent from a single ventricle, and from which it is distributed to the system before it is returned to the heart, which is thus exclusively pulmonic, may be divided into three sub-classes.

(1) *Dermopteri*, including all the *soft*, *apodal* fishes whose exo-skeleton and vertical fins have no really hard pieces, either bony or cartilaginous, but are simply *muco-dermoid* in structure, and whose endo-skeleton is unossified. Two orders, (a) *Cirrhostomi*, represented by the amphioxus, a very aberrant animal, having a longitudinal mouth with lateral cirrhi; (b) *Cyclostomi*, represented by the *Myxina*, (Hag) and *Petromyzon*, (Lamprey), with circular sucking mouths.

(2) *Sub-class. Osteopterygii*, (*Osseous Fishes*) consisting of all those fishes which have the endo-skeleton more or less completely ossified. Includes six Cuvierian orders, namely, (a) Acanthopterygii, (spiny-finned); (b) Malaco-pterygii abdominales; (c) Malaco-pterygii Sub-brachiati; (d) Malaco-pterygii Apoda; (e) Lophobranchii; (f) Plectognathi.

(3) *Sub-class. Chondropterygii* (Cartilaginous Fishes) have the highest organization of the whole class. Two orders (a) chondropterygians with free branchiæ, as sturgeons, &c.; and (b) with fixed branchiæ, as sharks, &c.

102. External forms of Fishes. Two sets of fins in most of the class, namely, vertical azygous fins and oblique fins in pairs; the latter never exceeding two pairs, one diverging from the scapular arch, the other connected with a rudimental pelvic arch, which may be placed either at the normal position, (abdominales) or under the throat, (Jugulares) or at intermediate positions, (Thoracici). The impair or azygos fins are *dorsal*, (one or two); *Anal* just behind the anus; *Caudal*, which may be *Homocercal*, that is, vertically symmetrical, an upper and lower piece being similar, and separated by a notch; or *Hetero-cercal*, as found in the cartilaginous fishes where the rays of the caudal fin are connected with the bodies of several caudal vertebræ, which run exclusively into the upper lobe of the fin, the lower being much shorter. Large gill openings behind operculum. *Lateral line* of pores, orifices of mucous glands.

103. Peculiarities of the Piscine Skeleton. No medullary canal in the long bones. No regular system of haversian canals and cancelli, but large, irregular, angular lacunæ with few but large radiating canaliculi. Bodies of vertebræ generally with cupped surfaces, working over convex intervertebral capsules. Very gradual development of the vertebral axis, from being a mere cellular and gelatinous "Chorda Dorsalis," without segmental divisions, as in the Amphioxus, to the condition found in *Lampreys*, where cartilaginous laminæ are developed within the folds of a fibrous membrane surrounding the Chorda Dorsalis, and which by the separation of its two layers above and below constitute the neural and hæmal arches in the Myxinoid family. Vertebro cranial axis divided into only three regions in most fishes, namely, *Cranial*, *Dorso-abdominal* and *Caudal*, there being no neck, or sacrum, and no distinction between Thoracic and Lumbar regions. In the Squalidæ, however, there is a cervical region. Use of Pectoral and Pelvic extremities. Structure of *hands* with its numerous rays indicating, however, mere irrelative repetition. Ribs attached to transverse processes, or to vertebral bodies. No sternum. Peculiarities of the cranium and face.

104. *Dermo-skeleton.*—(1) Skeleton of the vertical fins either *unjointed bony spines*, (acanthopterygii) or else *articulated cartilaginous rays*, (malaco-pterygii) resting upon and articulated by a chain link joint with the dagger-like *interspinous* bones. (2) Sub-orbital, supra-orbital, supra-temporal and labial scale-bones. (3) The more common *scales*, whether ossified or not, lying between cutis and cuticle, in a depression of the former. Four varieties of scales. *Placoid*, *Ganoid*, *Cycloid* and *Ctenoid* on which Agassiz founds his ordinal division of the class.

105. *Splanchno-skeleton.*—In addition to the more common pieces we note, (1) Branchial apparatus, consisting of the branchial arches, four in number, attached below to basi-branchial bones, and above to the cranium; toothed on their opposed surfaces. *Branchiostegal rays* diverging appendages of Hyoid arch. (2)

Pharyngeal bones behind branchial apparatus, often armed with teeth. (3) Oral teeth, often very numerous; generally mere calcified papillæ, whose base is consolidated with the bones on which they rest.

106. Alimentary apparatus the simplest consistent with the vertebrate type. Pulmonic bilocular heart with bulbus arteriosus, looking like a third cavity. Four gills on each side, in *most fishes*, receiving all the venous blood, and transmitting all the arterialized blood, without a second return to the heart, directly to the system, by the union of the branchial veins into an azygos *dorsal artery* after the head has first received its special vessels from the uppermost branchial veins. The ovaries of the female, known as the roe, occupy at the breeding seasons much the greater part of the abdominal cavity; ova escape into the ovarian sac, to be extruded prior to fertilization, which is subsequently accomplished by coming in contact in the water with seminal matter discharged by the male in a similar way from testicles occupying a similar situation. Fishes have cold blood with elliptical blood disks.

II. Class—Amphibia.

107. Cold blooded vertebrates with *naked skin*, most if not all of which in the early larval stage of their active existence have the anatomical and physiological characteristics of fishes, but subsequently undergo a metamorphosis one result of which is the development of lungs for breathing air, though a portion of the class retain their gills also, so as to be permanently amphibious in their powers of respiration. This section of the class termed *Perennibranchiate*. The others, named *Caducibranchiate*, lose their gills when they acquire lungs, and assume most of the reptilian characters. Hence by many zoologists the class *Amphibia* is ranked as a mere ordinal sub-division of the class *Reptilia*, under the name *Batrachia*. Reasons for rejecting this classification. Ordinal sub-divisions. (1) Anoura, which during metamorphosis lose the tail that previously was long and compressed. Other characters of Tadpoles. Branchiæ, in some species drawn into the cheek before metamorphosis. Impregnation effected externally during the extrasion of the ova. Common genera in this order are *Rana* (*Frog*) and *Bufo* (*Toad*). (2) Urodela.—Tail long and persistent, rounded in *Salamandra*, compressed in *Triton*. Feet, always four. Ribs very short. Vertebræ numerous and movable. Tympanum concealed. Impregnation internal. Common genera are *Salamandra* and *Triton*, the latter retaining the gills much longer than the former. To this order are generally assigned also the *Menopoma* and *Amphiuma*, which, however, are not *known* to possess branchiæ at any period of their existence, and hence Bell proposes to place them in a separate order under the designation *Abranchia*, but it is by no means certain, as he

himself admits, that these genera undergo no metamorphosis. (3) APODA.—Body elongate; slender; eel-like; *without feet;* tail very short, almost wanting; one lung larger than the other; sternum wanting; ears concealed; genus *Cæcilia*. The three foregoing orders constitute the *Caducibranchiate* section. The *Perennibranchiates* are all included in one order, named BRANCHIFERA (*Cuvier*), or AMPHINEURTA (*Bell*) with bodies elongate, formed for swimming; feet either four or two anterior only; tail compressed, persistent, branchiæ external, persistent and coexisting with rudimentary lungs. *Genera*, *Proteus*, *Siren*, *Menabranchus*, *Axoloti*. Changes in the arrangement of the branchial circulation coinciding with the metamorphosis; circulation now substantially reptilian, but differs by the permanent retention of the branchial vascular arches which unite to form the dorsal artery. Blood disks elliptical and very large.

III. Class—REPTILIA.

108. Vertebrates with cold blood, pulmonary respiration, trilocular heart (in the single ventricle of which the two kinds of blood received from the two auricles are mixed, to be distributed in part to the system, and part to the lungs,) and skin covered with hard and dry cuticle, forming in some imbricated scales, and in others broad plates. Blood disks ellipical. *Ordinal divisions.* (1) CHELONIA or *Testudinata*, covered with broad horny shells, exhibit a most remarkable consolidation of the skeleton. *Dorsal carapace* formed of spinous processes of dorsal vertebræ and the ribs. Sternal *Plastron* formed of expanded sternum and some *dermal* pieces. Head, tail and limbs of many species may be withdrawn into the box formed by the carapace and plastron, the latter being sometimes jointed in the middle. Scapular and pelvic arches lie within. Edentulous, but have sharp, horny beaks. Feet unguiculated with or without webs, or else enclosed in a paddle-like fin. (2) Order OPHIDIA, covered with scales. United by Bell with the *Lacertidæ* of the next order, under the designation of *Squamata*, which he contends is a more natural arrangement than the one commonly adopted. Skeleton remarkable for multiplication of trunk vertebræ (400 in Python) connected by a very moveable ball-and-socket joint; moveable ribs; no sternum; no locomotive members, and only in a few an imperfect pelvic arch. Head remarkable for the looseness of the connection between the bones that surround the mouth. Even the Tympanic pedicle and the mastoid bone to which it is chiefly attached, hang very loosely. Numerous small conical teeth of non-venomous species found in both jaws. Venomous serpents have two large poison fangs on the front of the upper jaw.

(3) SAURIA.—Separating the *Lacertidæ*, which like serpents, are covered with imbricated scales, and which are closely connected

with true serpents by an osculant group, the *Saurophidia*, that are apodal but otherwise Lizard-like, the remainder of the Saurian order may be designated by the term LORICATA, as being covered with *bony scutes*. Peculiarities of the Saurian type of skeleton demonstrated by means of drawings and actual preparations; alimentary apparatus; structure of lungs. Heart with *four cavities* in the crocodile, mixture of venous and arterial blood *outside* of this heart, the head receiving pure blood. Generation oviparous in all reptiles, though in some species the eggs are occasionally hatched in the oviducts, simulating viviparous generation.

IV. Class—AVES.

109. Oviparous vertebrates with warm blood, *double circulation* and double respiration; anterior or pectoral extremities organized for flight; body covered with feathers; mouth edentulous; blood disks elliptical.

Ordinal sub-divisions. (1) *Raptores* or *Accipitres*, with very strong talons, armed with sharp, hooked claws; beak also hooked and sharp, as eagles, hawks, owls, and other "birds of prey." (2) *Insessores* or "*perchers*," with feeble and unarmed toes, one directed backwards and three forwards. Beak generally pointed and *not vaulted above*; wings long and body erect. *Swallows*, *larks*, and the most common birds. (3) *Scansores* "climbers," two toes directed backwards and two forwards. Beak and wings as in the Insessorial order. (4.) *Gallinaceæ* or *Rasores* (scratchers) superior mandibles arched or vaulted; nares partly covered by a soft, inflated scale; gait heavy; wings short; toes as in the Insessorial order; but generally the nails are more blunt, and the males of some genera have a spur. Common fowl, partridge, pheasant, &c. (5) *Grallatores*, "waders," feet formed for wading; tarsus and metatarsus being very long, and the lower part of the leg naked. Crane, heron, snipe, woodcock, &c. (6) *Cursores* "runners," included by Cuvier in the preceding order, from which they differ, however, by the rudimental condition of their wings, which, when most fully developed, are still only fit for beating the air while the body is borne along by the rapid progression of the legs reacting against the ground, as in the ostrich. One genus (Apteryx) found in New Zealand, has only a scarcely discoverable rudiment of a wing on each side. (7) *Natatores* or *Palmapedi*, "swimmers;" web-footed; legs generally placed far back, rendering swimming easy but walking difficult. Several genera, as ducks, geese, &c., have their beaks covered with a soft skin.

110. *Anatomical peculiarities of Birds.* General shape of body and its several regions. Epidermic appendages, *feathers*, peculiar to the class; their form and structure. Cranial bones very early consolidated; upper jaw slightly moveable, with its lower jaw edentulous but covered with a horny beak. *Tympanic bone*

still separate and moveable, as in all other oviparous vertebrates. Cervical vertebræ from 9 to 23, and very moveable with double diarthrodial joints separated by a meniscus. Anchylosis of dorsal vertebræ. Bony *sternal* as well as vertebral ribs; extensive keel-shaped sternum in most birds, but nearly flat in the ostrich. Lumbar and sacral vertebræ soldered together and to the ossa innominata; pelvic arch incomplete below; scapular arch very firm and composed of a narrow rib-like scapula, lying parallel with the spine, and a thick strong *coracoid*, articulating by a strong joint with the sternum, so as to form a rigid buttress which prevents the shoulders from being drawn together by the powerful traction of the pectoral muscles. The two clavicles unite in front of the coracoid to form the *furculum* or merrythought; two carpal and two tarsal bones; three metacarpals partially united; three fingers; from two to four toes, most commonly the latter, of which the first looking backwards has two phalanges, the second has three, the third has four, and the fourth has five.

Digestive Apparatus. Mastication effected by the agency of the wall of a special stomach, called the *Gizzard*, lined internally by a hard, horny cuticle, the walls being formed chiefly of very strong muscles, whose fibres radiate from two central tendons. Use of the pebbles swallowed by *graminivorous* birds. *Ingluvies* or *crop* and *Proventriculus*, with its walls studded with gastric glands, both being in front of the gizzard. Small and large intestine; cloaca; very large, and more or less symmetrical liver, &c., &c. *Circulation double* as in man; blood warmer than that of mammals; blood disks elliptical and greatly smaller than in fishes and reptiles. *Respiration double*, that is, the blood besides being aerated in the lungs, is also partially exposed to the air in the systemic capillaries in most regions of the body, by means of air sinuses communicating with the lungs. Final causes of this arrangement. In both sexes the genital tubes open into a cloaca. Males generally destitute of an intromittent organ; copulation being effected by simple juxtaposition of the sexual orifices, by an eversion of the cloaca. Some aquatic birds have a true penis, which, when lax, is withdrawn into the cloaca, but projects when erect, and is grooved for the transmission of the semen.

V. Class—Mammalia.

111. Warm blooded vertebrates, having viviparous generation, with which there is invariably found to coincide the presence of *mammary glands*, on the secretion of which the new-born mammal is fed. Circulation double and complete. Respiration complete but single. Body invested more or less completely with *hairs*, or some homologous modification of epidermic cells, except in a few naked species. Two sub-classes. I. Placentalia with a truly viviparous generation; the young being born in a comparatively

matured state, after having been connected with the mother by means of a placenta. II. IMPLACENTALIA with only *ovo-viviparous* generation. In this case, although a living embryo is extruded, it is very immature, never having had a placental connection with the maternal system, and is consequently destined to lead an exclusively *organic life* for some time after birth, during which it is firmly fastened by its mouth to the maternal teat.

Ordinal Sub-divisions.

I. Sub-Class—PLACENTALIA.

112. (1) *Rodentia*; (*gnawers*); two front teeth in each jaw, chisel-shaped for gnawing, covered by enamel only in front; variable number of molars. Squirrel; rat.

(2) *Edentata* (*without teeth*); wanting either all the teeth or having only imperfect molars. Ant-eater, armadillo, sloth.

(3) *Ruminantia*, which ruminate or chew the cud. Hoofs cleft; except the camel tribe all want incisors in the upper jaw; the most common dental formula being, incisors, $\frac{0}{6}$, no canine; molars $\frac{6}{6}$-$\frac{6}{6}$; with the same exception, all have horns, at least in the male sex.

(4) *Pachydermata* or *thick-skinned* mammals, comprise four tribes, viz.: (a) *P. Proboscidea*, as the elephant. (b) *P. Ordinaria* as the hog, &c. (c) *P. Solidungula*, with a single digit in each foot, as the horse; and (d) *P. Cetacea Herbivora*, as the dugong, &c.

(5) *Cetacea*; posterior extremities wanting; anterior converted into swimming paddles; horizontal tail-fin; some have a dorsal vertical fin. Fat, called blubber, in the very substance of the skin. Nostrils on the top of the head, by which cetaceans *spout*. Peculiar disposition of vascular sinuses in adaptation to their habit of remaining submerged for some time; whales, porpoises, &c.

(6) *Carnivora*, or beasts of prey, comprising three tribes, viz.: (a) *Digitigrada*, as the *Felidæ* or Cat tribe, and *Canidæ* or dog tribe. In the former, retractile and sharp claws, and peculiar *carnivorous teeth*. Claws of Canidæ blunt and not retractile. (b) *Plantigrada* with teeth partly adapted to vegetable diet, as bears. (c) *Amphibia* or *Phocidæ*, with forms adapted for residence in water. Seals.

(7) *Insectivora*.—Special conformation of teeth adapting them for crushing hard skins of the coleoptera. Moles, shrews, &c.

(8) *Cheiroptera*, (winghanded) anterior extremities organized for flight by enormous elongation of fingers, which support a delicate duplication of skin. Teeth irregular. Bats.

(9) *Quadrumana*, with opposable thumbs on all four of the extremities, (at least in most of the genera) all being prehensile

as well as locomotive members. Dental formula in most of the families the same as in man; but some have an additional molar on each side of each jaw. Monkeys and apes.

(10) *Bimana.*—Anterior extremities organized exclusively for prehension, terminating in hands of which the opposable digit is a more perfect thumb than we find on any of the extremities of Quadrumana. Man, the sole species of this order.

II. Sub-Class—Implacentalia.

(11) *Marsupialia*, (pouched animals). Young born very immature, and conveyed in some way to the *marsupium* or abdominal pouch of the mother, where they grasp the teats with their mouths so firmly as to appear organically united. Marsupial bones and their use in the two sexes. Uterus and vagina double and open into a uro-genital canal, which has a common opening with the rectum, but there is no true cloaca. Opossum, kangaroo, &c.

(12) *Monotremata.*—Implacental mammals with a cloaca common to the uro-genital canal and to the rectum. Even in the male, the uro-genital canal opens into the cloaca, but the penis is perforated, and during erection has its hinder orifice drawn to that of the uro-genital canal, so as to receive the semen which is projected through numerous papillary orifices on its free end. Two uteri and vaginal canals, which are quite separate on the two sides, and open by separate orifices into the uro-genital canal. A very aberrant group, resembling birds in several other respects, besides the disposition of the genital organs. Only two known genera, namely, the *Ornithorhynchus* (Duck-bill) and *Echidna*, covered with strong spiny bristles, which it can erect like a hedge-hog. Found only in New Holland, where also all the existing marsupialia reside, except the *Didelphys* (opossum) which is only found in America.

113. *Anatomical peculiarities of Mammals.*—Two pairs of extremities present throughout the class, except only in the true *Cetacea* and the *Cetacea Herbivora*, which lack the hinder extremities, and have only a rudimental pubes. In all, the head is marked off from the trunk by a neck, though this is much obscured in the fish-like Cetaceans. All except Cetaceans more or less completely covered with hair, sometimes modified in a very extraordinary way, as in the *quills* of the *Porcupine*, or the imbricated *scales* of the *Pangolin*, or in the ossified plates of the *Armadillo*, or in *wool*, which is a kind of hair very fine and twisted in all directions, or finally in *down*. The Rhinoceros has an azygos solid horn, formed of agglutinated fibres like whalebone, growing upon the nose. Ruminants, except the *Camelidæ*, have a pair of frontal horns, either solid and permanent like the Giraffe, or solid and annually deciduous as the deer-tribe, or finally *hollow* and permanent. The solid horns are bony processes from the frontal bone, covered by

a fine velvety skin, which, in the deciduous variety, dies at a certain period of the year, leaving the horns or *antlers* bare, when they too soon die, and drop off to be replaced by a new set, larger and with more branches than the old. The hollow horns are hollow cones of horny tissue implanted upon bony prominences filled with air cells that communicate with the nose. Great expansion of the neural arches of all the cranial vertebræ, especially the parietal, for the protection of the progressively developing brain. In most of the class an additional cranial element is gained by the expansion of the distal end of the diverging appendage from the superior maxillary bone, namely, the squamosal bone. Tympanal bone displaced by the intervention of the squamosal and reduced in size; mandibular arch (lower jaw) coalesced into one piece on each side, (these often united at the symphisis) always articulates with the temporal bone by an *undivided condyle;* occiput articulates with atlas by *two condyles;* cervical vertebræ always seven in number, except in the Pangolin, which has only six, and the three-toed sloth which has eight or nine. Coracoid bone, so conspicuous an element of the scapular arch in the oviparous vertebrates is not, in most mammals, sufficiently developed to reach the sternum; clavicles more frequently connect the scapula with the sternum, but they are often wanting, as in horses and most mammals which use the anterior limbs exclusively for station and progression by moving only forwards and backwards.

Digestive apparatus.—Peculiar straining apparatus of the *whalebone-whale* (*Balæna mysticetus*). Numerous small, conical *reptilian* teeth of the porpoise, dolphin, armadillo, &c. In mammalian teeth, except those which grow *from a persistent pulp* (as the tusks of the elephant, the chisels of the Rodentia, and the molars of the Edentata) the dental cavity is closed in at its lower part, and the base of the tooth is prolonged into a fang, which is implanted in a proper socket formed by a projection of the bony substance of the jaw that grows up to invest it; this is peculiar to this class, and further, no known vertebrate but a mammal has teeth implanted by bifid fangs. Fleshy lips, tongue, salivary glands, velum pendulum palati, epiglottis, muscular pharynx, and œsophagus. Stomach either (1) *simple*, or (2) *complex*, as in kangaroo, &c.; or (3) *compound*, as in Ruminants. Small and large intestine. Gall bladder sometimes wanting, as in the horse, &c. Heart double. Portal circulation. Respiration single. Special provisions for the safety of aquatic mammalia, who remain submerged for some time. Blowing apparatus of Cetaceans.

The skin of all quadrupeds contains innumerable *sebaceous follicles*, furnishing an unctuous matter for lubrifying the skin. Sometimes a number are aggregated together so as to form secreting pouches, as just below the orbit in stags, furnishing a secretion commonly called the "Stag's tears." Often such pouches furnish a highly odorous material, especially in the vicinity of the organs of generation, as the castor glands of the Beaver, the musk gland

of the musk Deer, and the anal glands of the Carnivora, which have an intolerable stench in the Skunk and Polecat. Genital apparatus among the Placental orders does not deviate largely from the human type; and that of the Implacentalia has already been noticed.

The peculiarities of the *kidneys*, of the *absorbent system of vessels and glands*, of the *brain and organs of sense* of Mammalia and other vertebrates, will be noticed in connection with the physiology of these organs.

ON THE OBJECTS AND PRINCIPLES OF ZOOLOGICAL CLASSIFICATIONS.

114. Why this topic was reserved for this point in the course of lectures. Immense number of animal species, each with its double name generic and specific. Definition of a *natural* classification. Relation of *analogy;* relation of *affinity* or *homology*, which is more fruitful as the basis of a natural classification. Illustration from the comparison of Whales with Fishes on the one hand, with which they are connected by relations of analogy, and with quadrupeds on the other, with whom they differ in general appearance and habits, but agree in all the important features on which the class Mammalia is founded. Hence to class whales with man and beasts is a far more *natural* arrangement than that which the unlearned make from contemplating their fish-like habits. So, too, Bats are *unnaturally* classed with Birds. their real place being with other mammals. An *artificial* classification is one which does not necessarily indicate the natural affinities of the objects classified, as the Sexual System in Botany. Possible advantages of such a classification, if skilfully constructed. Characteristics of a *natural* classification. Advantage to be derived from having some single and easily discovered external character, *even though it be artificial*, as an index or exponent of a group of natural characters with which it is found to coincide. Examples, *feathers*, a sign of all those natural characters which are indicated by the term Bird; hair, significant of mammalian organization, &c. &c.

115. The entire collection of animals called the Animal Kingdom. The primary divisions, termed sub-kingdoms, have each, in addition to the characters which belong to the whole kingdom, some other features common to all its own members, but not possessed by other sub-kingdoms. The zoological sub-kingdoms, founded on the varying types of nervous system, which seem to govern the whole organization, are exceedingly natural, if we except only the *Protozoan*, which is founded on negative characters. The primary divisions of a sub-kingdom termed *Classes*. Most of the animal classes are *natural* groups, as for example, the Vertebrate classes, *Mammalia*, *Aves*, *Pisces*, and even *Reptilia*,

if we exclude the Batrachians, and raise them to the rank of a separate class, *Amphibia*. But there are some instances of *classes* founded on artificial characters, as *Entozoa*, a group which really includes animals belonging to three different sub-kingdoms. The immediate sub-division of classes termed *Orders*, which are more frequently founded on some single character, and therefore less natural than either the higher or the lower groups. Orders are sub-divided into *Tribes* or *Families;* and the animals included in such a group are marked by a *natural family likeness*, as for example, the *Canidæ*, the Dog tribe or family, which includes the Dog, the Wolf, the Fox, and the Jackal; and the *Felidæ*, including the Cat, Lion, Tiger, Leopard, &c. *Families* include a number of *Genera*, that is, collections of animals resembling each other in *all* the important features of their organization; and finally, a genus includes, or may include a large number of *species*, which is the term applied to all those individuals which are *constantly* marked by the same characters with only such slight *occasional* variations as are compatible with the idea of a *common parentage*. Such a group is altogether natural therefore. Any *constant* or *invariable* difference, however slight, is yet adequate to indicate a difference of species, a necessary consequence of the law of resemblance between parent and offspring. To go over the same ground in the reverse order, we observe that nearly allied species, that is, species recognized as different by some constant point of distinction, which however is intrinsically unimportant, while the points of resemblance are numerous, and have respect to all the important features of organization, are grouped together as one *Genus*. In the same manner closely allied genera are ranked as one *family* or *tribe*. *Families*, resembling each other in natural, or even in certain artificial characters, are placed in the same *order;* allied *orders* make a *class*, and *classes* having a certain degree and kind of affinity, are grouped together as a sub-kingdom. "Thus as we pass from species to genera, from genera to families, from families to orders and from orders to classes, the characters of agreement become fewer and fewer; whilst those of difference manifest themselves more and more strongly. And when we arrive at *classes*, we may generally say that the points of difference are stronger than those of agreement." *Typical representatives* of any natural group of animals. Genus *Felis*, a typical genus of the family *Felidæ*, the latter being a typical family of the order Carnivora; the order *Insessores*, a type of the class Aves. So Annelidans and Myriapods may be regarded as retaining more of the distinctive characters of the sub-kingdom Articulata, than either the Arachnidans, Crustaceans or Insects, all of which in their higher forms diverge in different directions and nearly equal degrees from the common fundamental type. *Aberrant* groups. *Osculant* groups. Examples: Sub-class *Cirrhopoda* are aberrant Crustaceans, being osculant between the typical Crustaceans and Acephalous Mollusks. The class *Bryozoa* osculant between the mol-

luscan sub-kingdom to which it truly belongs, and the Radiate class *Polypifera*, to which it bears some points of resemblance.

ON SPECIES AND VARIETIES IN THE ANIMAL KINGDOM.

116. Species defined by CUVIER to be the "collection of all the beings descended the one from the other, or from common parents, and of those which bear as close a resemblance to these as they bear to each other;" by others to be "a race of animals or plants marked by *any* peculiar character which has always been *constant* and *undeviating*." These are substantially the same, the one asserting what is implied in the other. May be deduced from the law of resemblance between parent and offspring, upon which depends the possibility of identifying species. Flexibility of this law within certain limits, under the operation of external influences; the results of the partial modification thus induced being then perpetuated under the operation of the original law. Illustrations derived from the transmission throughout a large family of peculiar traits originating in a given individual ancestor, when a peculiarity thus acquired becomes permanent in a group of individuals breeding among themselves. Such a group is designated a *variety*. A variety is thus a group of animals marked by the permanent reproduction of some distinctive feature, *which feature however, may be shown to have been acquired in superaddition to, or as a modification of the characters of the species to which the animal truly belongs.*

117. Tests of *unity of species* in the case of groups of animals characterized by such permanent peculiarities as to constitute the distinctions of *varieties*. (a) Historical evidence. Varieties of the hog, of the horse, of the dog, and of horned cattle now found in America, and known to have issued from domestic breeds introduced by Columbus and his followers. Notice of the kind and extent of diversity exhibited by these varieties as compared with the original stock, (1) as to structural characters; (2) as to physiological and psychological qualities. Habits *acquired* by certain animals and then transmitted to their offspring, which thus *inherit* traits originally *acquired* by the parent.

(b) Value of structural differences in the discrimination of species. The peculiarities which mark a variety being liable to disappear on the removal of the causes which originally produced them, there are generally found intermediate gradations tending to connect the most extreme varieties with each other, and with the typical characters of the original and common stock. On this ground, all the varieties of dogs are assumed to belong to one species, since it is impossible to mark off the boundaries of more than one species, by reason of the intermediate grades which connect the extreme varieties with each other and with the wild stock whence all have, doubtless, sprung. On the other hand a differ-

ence of species is indicated "when the characters which separate two races are transmitted with *complete uniformity*, when there are no intermediate gradations tending to connect them, and when no such tendency to variation has manifested itself in either race, as shall make it probable, or, at any rate, possible, that their differences may be attributed to some unusual divergence in the characters of the offspring from those of the parents." (*Carpenter—"Varieties of Mankind."* (c) Value of physiological and psychological peculiarities in the discrimination of species—often a surer criterion than structural characters. Sterility of hybrids rendering impossible the existence of a hybrid species. Constant and uniform agreement among animals of the same species, but of diversified varieties, as to the great laws of the vital functions, such as those "which express the periods and duration of life, the economy of the sexes, and the phenomena of parturition and reproduction." Decided differences in regard to the same peculiarities among races which, though very nearly resembling each other are yet specifically distinct.

Every species characterized by the possession of instincts and propensities peculiar to itself, so that the instincts of different, though nearly allied species may differ remarkably, while those of different varieties of the same species, notwithstanding very strongly marked diversities of physical structure, are fundamentally the same.

118. Application of these principles to the case of the Races of Mankind. Setting aside the historical evidence, on account of the doubts entertained by some naturalists as to the correct interpretation of the teachings of Scripture on this point, (although the statements of the inspired writers appear to be sufficiently explicit, and in accordance with the inductions of science,) it is to be observed that the peculiarities which distinguish the several races of mankind, run into each other by changes so numerous and gradual as to make it utterly impossible to determine the boundaries of more than one species. No two naturalists can agree as to the number and characteristics of the different races. Taking the Western Europeans and their American descendants, as one extreme, and the Bushmen of Southern Africa as the other, we find intermediate grades which connect these very remote extremes by gradual transitions. Again, within the limits of a single variety there occasionally appear as an accidental anomaly, traits of conformation identical with those which distinguish a different variety. And finally, on this head, an entire race marked by certain peculiar traits of conformation have, on changing their mode of life, after some centuries lost those traits and acquired others. Three general types, into which the varieties of the human race fall, as regards their physical characteristics. (1) *Prognathous type* of savage and hunting tribes; (2) Type of the *Pyramidal* skull, found in the nomadic and pastoral tribes; (3) Type of the *oval* or *elliptical* skull, belonging to those races that have been subjected to

the influences of civilization. "Turks of Europe now exhibiting the oval skull, are known to be descendants of the Turks of middle Asia, who exhibited the pyramidal form. So, too, the Magyars of Hungary." "The very fact of the extensive dispersion of a race, and of its existence under a great variety of external conditions implies a marked capacity for variation; since without such capacity the race could not continue to flourish." (Carpenter, loc. cit.) So far, then, as structural peculiarities are concerned, they lead to the doctrine of the specific unity of the several races of mankind. "The conformity among these races as to physiological phenomena, furnishes a yet stronger argument; for instance, the power of indefinite cross breeding, often with the result of improving the parent stock. The average duration of life under the same circumstances, is the same for all; the extremes of longevity the same; the epoch of the first and last menstruation and the length of the intermenstrual interval, the duration of pregnancy, the periods of dentition, &c., &c., all point to the conclusion of the unity of the human species, while they establish a specific difference between man and the most anthropoid apes. Again, the correspondence between the different races of mankind in respect to physical endowments, leads to the same results, all having the same intuitive convictions, the same primary faculties of mind, the same kind of susceptibility to improvement, though, perhaps, not always equal in degree, and the same feelings of fear or hope in reference to a future state of existence beyond the grave. (*Prichard.*)

119. In accordance with the terms of the definition given in § 116, it has commonly been held that all individuals belonging to the same species must have sprung from one original pair. Thus Latham says, "a multiplicity of *protoplasts* (*original parents*) for a single species is a contradiction in terms. If two or more such individuals or pairs, as like as the two Dromios, were the same protoplasts to several classes of organized beings (the present members being as like each other as their ancestors were,) the phenomenon would be the existence in nature of more than one undistinguishable species, not the existence of more than one protoplast to a single species." (Latham—Races of Mankind.) Notice of recent attempts to draw a distinction between unity of species and community of origin, and to show that the several species were originally created in the same relative numbers in which they now exist,—that all the original individuals of the same species possessed the same *essential* nature, modified, however, in accordance with the special conditions in which each was destined to exist. Notice of the argument of Agassiz, the leading supporter of this novel doctrine, in supporting which he very eloquently demonstrates the specific unity of the races. Opposite conclusions of eminent Zoologists and Geologists. Thus, Prof. E. Forbes rejects the whole hypothesis of the radiation of species from separate centres, and avers "that the peculiarities in the geographical distribution

of existing species are quite reconcileable with the idea of migration from single centres, and that, generally speaking, they lead *necessarily* to that idea." (CARPENTER, loc. cit.) So, too, Sir. C. Lyell declares, that "there appears to be no sound objection to the doctrine that all the leading varieties of the human family have originally sprung from *a single pair*."

120. Tabular view of the leading divisions of the Animal Kingdom.

A. Sub-kingdom *Protozoa*. No positive characteristics, except such as belong to all animals. The distinctive character is the negative one of the absence of a nervous system; no special vascular system; no localized respiratory apparatus; genital system diffused, &c., &c.	1. Class. *Polygastrica*. Infusorial, microscopic. Supposed to be characterized by multiple stomachs; but this character is doubtful, and the class is probably not natural. 2. Class. *Rhizopoda*. Mere organic cells filled with granular semi-fluid matter, capable of altering their shape by projecting the integuments in various directions. Most species loricated, with *root-like* feet projecting through pores in the shell. 3. Class. *Porifera*. Motionless and unirritable; flesh supported on a fibro-corneous skeleton, covered with *pores* and vents.
B. Sub-kindgom RADIATA or CYCLONEURA, characterized by the presence of a nervous system which, *when discernible*, consists of nervous threads arranged in a circular form around the mouth with radiated branches. In some the nerves have not been discerned, (ACRITA,) but their actions imply the existence of such organs. Circular symmetry of the body, or of the parts around the mouth. Alimentary canal with its own special walls in all except the Hydroid Polypi. Blood-vessels first appear in this group, at first as mere continuations of the alimentary passages (*Acalephæ*), but soon as distinct organs with pulsatile walls in some places (*Echinodermata*), but entirely wanting in most *Polypifera*. Respiratory apparatus also gradually evolved, being localized in the Holothuridans as an arborescent set of tubes. Generative apparatus, very simple and of the monœcious type in Polypi, rises to the diœcious type in the other two classes. Alternate generation.	1. Class. *Polypifera*. Soft, inarticulate, acrite. Of saccular form with orifice surrounded by prehensile tentacula. Sometimes single; more frequently composite, with a common polypary partly fleshy and partly horny or stony. Two orders, *Hydroida* and *Actinoida*. 2. Class. *Acalephæ*. Mostly acrite. Of various shapes; of glassy transparency and gossamer texture, with an enormous relative amount of water; stinging property; phosphorescence. Four orders. *Pulmograda*. *Ciliograda*. *Cirrhigrada* and *Physograda*. 3. Class. *Echinodermata*, with a distinctly radiate nervous system; a contractile skin having, commonly, calcareous plates imbedded in it. Many have prickly spines; many also have tubular cirrhi for locomotion; but the class is *naturally* characterized by its advanced grade of organization as compared with the other radiate classes, having a distinct vascular system and a progressive developement of a distinct respiratory apparatus, &c. &c. Six *existing* orders, as *Crinoidea*, *Ophiurida*, *Asteriada*, *Echinida*, *Holohurida* and *Sipunculida*.

C. Sub-kingdom. MOLLUSCA or HETERO-GANGLIATA. Hetero-gangliate nervous system. Body unsymmetrical, soft and without dermoskeleton, having only a muscular skin called "*Pallium*" or mantle. Whole body often inclosed in a *testa* or calcareous shell, univalve, bivalve, or multivalve. Preponderating development of nutritive apparatus and great deficiency, in most cases, of the powers of animal life. Long, convoluted intestinal tube; large and active liver. Heart, found in all but the *Bryozoa*, systemic except in *Tunicata*, where it is alternately systemic and pulmonic. Distinct respiratory apparatus in all except the class *Bryozoa*, and in all except the *Ascidian* family of the Tunicata it opens at or near the anus.

Multiplication by budding in the lower classes, *Bryozoa* and *Tunicata*. Hermaphrodism quite common among Gasteropods. All the higher classes organized on the Diœcious type.

1. Class. *Bryozoa*. Zoophytic mollusks; microscopic; no heart; no special respiratory system. Single nervous ganglion.

2. Class. *Tunicata*. Low molluscans inclosed in a leathery *tunic* with two orifices. Single nervous ganglion. Heart with one cavity. Respiratory chamber.

3. Class. *Palliobranchiata* or *Brachiopoda*. Bivalve mollusks with the whole mantle arranged for respiration.

4. Class. *Lamellibranchiata*. Bivalves with respiratory organs in the form of four lamellæ between the two lobes of the mantle. One or two muscles; three or more ganglia. *All the foregoing are acephalous.*

5. *Gasteropoda*. Under surface of the belly, or a part of it developed into a disk adapted for sluggish locomotion. Distinct head bearing tentacula, eyes, oral apparatus, &c. *Supra Œsophageal* ganglion or brain; other scattered ganglia; one order breathing air by means of *pulmonary chambers*, others breathing water by localized branchiæ; most inhabit univalve shells.

6. *Pteropoda*. With lateral alar appendages for swimming.

7. *Cephalopoda*. Mouth in the centre of a disk, surrounded by large fleshy arms. Very large brain protected, in some species, by a rudimental cranial cartilage.

D. Sub-kingdom. ARTICULATA. HOMOGANGLIATA, or DIPLONEURA. Animals which exhibit the Homogangliate type of nervous system; that is a nervous system consisting mainly of separate ganglia, which are similarly arranged in the different segments of the body. In general the body is composed of *similar segments*, succeeding each other longitudinally and by their connection presenting the jointed appearance from which the most common name (*Articulata*) of the sub-kingdom is derived. In the more typical forms there is a double ganglion in each segment, the first or cephalic segment having its ganglion *above* the œsophagus, while the ganglia of all the succeeding segments are *ventral*, or below the alimentary canal. In the lower forms the ventral chain of ganglia is replaced by a double nervous *cord* without ganglia, and hence the use of the term DIPLONEURA, as one of the synonymes of the sub-kingdom.

1. Class. *Entozoa*, not a natural group; including the members of at least three classes belonging to as many different sub-kingdoms, but all exhibiting a *tendency* to the articulate type in which the highest of them culminate. These form the Nematoid order, characterized by diploneurose grade of Homogangliate type. Straight alimentary tube; a few longitudinal blood-vessels; diœcious type of genital apparatus; very long and convoluted ovaries; vulva in front of the middle of the body.

2. *Rotifera*. Microscopic and infusorial articulates with one or more *rotæ* or fleshy lobes being vibratile cilia.

3. *Annelida* or *Annellata*. Soft-skinned vermiform articulates either entirely apodal (Leech), or with only rudimental legs in the form of unjointed setæ; nonparasitic; elaborate development of vascular system with arteries, veins and multiple hearts, (i. e. portions of the arteries dilated and pulsatile); ventral chain of ganglia. The absence of these characters in the *non parasitic* Planariæ causes them to be ranked with Entozoa, leaving the Annelida a *natural* class.

4. Class. *Myriapoda*. Articulates of numerous similar segments, all of which, except the two terminal ones, bear one or two pairs of feeble but jointed legs. Breathe air by tracheæ.

Sub-kingdom—ARTICULATA. (Continued.)

Some are without legs, (vermiform.) Some have locomotive appendages to all the segments except the two terminal ones, (myriapoda) others have such appendages to special segments only.

Mouth sometimes suctorial, and more or less circular, but when armed with mandibles, maxillæ, &c., these are always at the sides and move laterally. Every variety of alimentary, circulatory and respiratory apparatus found in the different classes of this sub-kingdom. The diœcious type of generative apparatus prevails, but there are instances of hermaphrodism in the lower classes.

Articulate classes. (*Continued.*)

5th class.—*Insecta.* Body in the embryo state consisting of thirteen segments, which subsequently in most species become more or less consolidated into three regions, namely, head consisting of one segment, thorax of three, and abdomen of nine. In a few there are fourteen, of which two form the head, (Hymenoptera and Diptera.) Three pairs of legs attached to thorax; most have two pairs of wings; one order has only one pair, and some orders are entirely *apterous.* Tracheary respiration. Vasiform heart or dorsal vessel. Blood vessels mostly lacunar passages. Salivary, biliary, urinary, ovarian and testicular organs, all tubular; generative organs always diœcious. Most undergo metamorphosis, passing through the several conditions of Larva, Pupa and Imago.

6th class.—*Arachnida.* Air-breathing articulates with four pairs of legs. Head and thorax united into cephalo-thorax; no antennæ; but very large maxillary palpi which appear like a fifth pair of legs, especially in the *Scorpionidæ*, or *Pedipalpi.* Two orders: *Pulmonaria*, breathing by air chambers, and having a well developed vascular system; and *Trachearia*, breathing by ramified tracheæ.

7th class.—*Crustacea.* Embracing all water-breathing articulates with jointed locomotive members, and divided into four sub-classes. (1) *C. Malacostraca*, the soft shelled or ordinary crustaceans, containing the familiar genera, crabs, lobsters, &c.

(2) *C. Entomostraca*, minute crustaceans of stagnant water, often enclosed in bivalve shells.

(3) *C. Suctoria.* External parasites; aberrant; osculant between true Crustaceans and Entozoa.

(4) *C. Cirrhopoda.* Soft, acephalous, with cirrhiform arms; muscular and mantle-like skin; testaceous; very aberrant, osculating with molluscans, but yet distinctly articulate in the arrangement of the nervous system, and in lateral symmetry with a faint indication of segmental structure. In the larval condition it is free, and resembles an entomostracan. When mature, it is enclosed in a shell, and fixed either by the fusion of its shell to the rock, (*Sessile order*) or by means of a long contractile pedicle. (*Pedunculated order.*)

E. Sub-kingdom—VERTEBRATA, SPINI-CEREBRATA OR MYELENCEPHALA.

Animals with a cerebro-spinal axis; that is, a dorsal column of ganglionic matter in one continuous cord, swelling out at the anterior end into a multiple mass called the brain; the whole being lodged in and protected by a jointed bony case, composed of a series of annular segments called vertebræ. Generally five senses. Blood always red, a character due to the blood disks which are peculiar to the members of this sub-kingdom. Nutritive apparatus well developed in correspondence with the rapid waste of the active nervous apparatus, and exhibiting spleen, pancreas, portal system and absorbent system, in addition to the organs found among the higher invertebrata. Respiratory, circulatory and generative apparatus variable in the different classes.

1st. class.—*Pisces.* Cold blooded, breathing water by localized gills; circulation single and pulmonic; body generally covered by scales: locomotion effected chiefly by lateral flexions of the trunk and tail. Generation oviparous, the ova being fertilized after extrusion in most cases.

2d. class.—*Amphibia.* Cold blooded vertebrates, which when first hatched have the anatomical and physiological characters of fishes, &c. Subsequently undergo a metamorphosis, as the result of which they acquire lungs for breathing air and other reptilian characters. Skin naked. Generation oviparous.

3d class.—*Reptilia.* Cold blooded; breathing air by means of lungs. Circulation imperfectly double, the two kinds of blood being mixed in a single ventricle, or shortly after issuing from two ventricles. Body covered with scales, or else with bony scutes. Generation oviparous. Three orders presenting as many different types of reptilian development, namely, *Chelonia*, *Ophidia*, and *Sauria*.

4th class.—*Aves.* Warm blooded, breathing air by lungs and disseminated sinuses, making a *double* respiration. Circulation completely double, or heart with four cavities. Body covered with feathers; anterior extremities formed into wings. Generation oviparous.

5th class.—*Mammalia.* Warm blooded. Single respiration by localized but very perfect lungs. Circulation as in birds. Body covered with hairs; anterior extremities organized for station or for prehension, very rarely for flight, (Cheiroptera—*Bats.*) Generation viviparous, or, among the *Implacentalia* ovoviviparous.

Commenced on the 26th of Dec

SPECIAL PHYSIOLOGY.

CLASSIFICATION OF THE FUNCTIONS OF MAN.

121. The special functions are subservient to one of two purposes, the well-being of the individual or the perpetuation of the race. Hence the basis of a primary division into two great sections. (I.) Those which have reference to the life of the individual being; and (II.) Those which look to the propagation of the species. The first of these sections sub-divided into two subordinate classes, viz.: (1) Those which are subservient to the development, growth and maintenance of the fabric, and which are therefore termed *nutritive or vegetative functions*, or the FUNCTIONS OF ORGANIC LIFE; and (2) those which serve to establish relations between the individual and the surrounding world, or FUNCTIONS OF RELATION which, being peculiar to animals, are also called FUNCTIONS OF ANIMAL LIFE. The second great section, embracing the FUNCTIONS OF REPRODUCTION, as executed by man and other higher animals, both vertebrate and invertebrate, will admit of a similar binary sub-division; but inasmuch as the *essential* part of these functions is exclusively *organic*, it will be convenient to class them with the nutritive functions pertaining to individual life under the general term, *functions of organic life.*

A.—FUNCTIONS OF ORGANIC LIFE.

I. *Functions of Reproduction or Generation.*

122. These consist (1) of acts executed by parents of different sexes, and which, although in man and the higher animals generally they involve incidentally the co-operation of *animal functions*, are yet organic in their *essential* nature, as they are exclusively so in lower animals and in all plants. (2) Of a series of intra-oval and intra-uterine developments constituting the evolution of the embryo.

II. *Functions of Nutrition or Assimilation.*

These consist in a series of acts whereby crude alimentary matter is converted into pure arterial blood, and the several parts of the fabric are developed and maintained at the expense of the blood, with certain incidental phenomena important to the in-

tegrity of the system. (1) *Digestion;* (2) *Chylosis;* (3) *Hæmatosis;* (4) *Respiration* as a means of the ingestion of oxygen; (5) *Circulation;* (6) *Secretion;* (7) *Nutrition;* (8) *Respiration* as a means of excreting carbonic acid; (9) *Urinary, Biliary, Cutaneous* and other excretions; (10) *Calorification.*

B.—FUNCTIONS OF RELATION, OR OF ANIMAL LIFE.

These include the functions of the nervous system and the actions of those muscles which in *respondence to nervous* stimulation effect the different movements of the trunk and its appendages. By the instrumentality of these acts even in the lowest grade of their manifestation, the simplest animals, save only those unconscious organisms called *Protozoa*, are brought into relation with the external world in two ways, (1) by *receiving* and *feeling impressions* of external agents on the organs of sense (*sensorial faculty*), and (2) by reacting on external objects by means of the muscles and bones, under the stimulus of a nervous force generated by the will (*volitional exercise of the motorial faculty*), or else excited by a prior action of an impressed nerve independently of either consciousness or volition. (Physico-reflex excitement of the motorial faculty.) In this connection are to be noticed the phenomena of animal instinct, and the connection between the mind and the brain as its instrument.

FUNCTIONS OF ORGANIC LIFE.

I. FUNCTIONS OF GENERATION.

123. Reasons for commencing the course with the consideration of this subject. Statement of certain general laws of generation. (1) Omne vivum ex ovo—proof of this law. (2) Law of resemblance between parent and offspring. Qualifications of this law. (*a*) Admissibility of variations, so as to form *varieties* within the limits of species, when the variations are inherited and transmitted to a group of individuals which are isolated from those of the same species that do not exhibit the same peculiarities. (*b*) The phenomenon of "alternate generation" another apparent exception. Statement of examples and true interpretation of the phenomena.

(3) Susceptibility of multiplication by budding (gemmiparous reproduction) and by spontaneous division (fissiparous), exhibited by certain low organisms. But in such cases it would seem that developmental power is *expended*, and the race would be annihilated after a time, unless this power were renewed in some other way, as (4) *True Generation*, which seems always to require the

union of the contents of two cells, the *female or germ cell*, and *the male or sperm cell*, whether these be found in the same individual (Monœcious, Hermaphrodite, or Androgynous type), or in different individuals (Diœcious type). Three principal modes of effecting this union observed in the vegetable kingdom, but only one in the animal world.

124. *Action of the Female in Generation.*—Essential element of the female generative apparatus a cell of peculiar endowments, the "*Germ Cell.*" Diffusion of such cells as also of the male or "Sperm Cells," in a few of the lowest animals, with whom multiplication by budding or by division may present the conditions of true generation. Germ cell, under the name of *germinal vesicle*, with its *germinal spot* in its centre, is found in the centre of a mass of oily and albuminous matter, called vitellus (yolk), inclosed in a thick membrane, the *membrana vitelli* or zona pellucida, the whole structure being termed *ovule*, or when fertilized, *ovum*. *Ovarium*, any special arrangement of tissues for the development of ova. *Oviduct*, tube for extrusion of mature ova.

TABULAR VIEW OF THE VARIETIES OF OVARIES.

125. (1) No true ovarium, ova being developed throughout the general parenchyma, as in the *Porifera* or *Sponge tribe.*

(2) Ova developed in a mass in particular localities, but without any special arrangement of the tissues; as at the base of the body in the genus *Hydra*, the sperm cells being developed near the base of the tentacula.

(3) Ova developed in the substance of a simple membrane, not arranged into a tube or sac, and when mature, being discharged first into the general peritoneal cavity, whence they issue by various means; as in the *Actiniform Polypi*, *Eels*, *Lampreys*, *Frogs*, *&c.*

(4) Ova developed in the substance of a membrane forming the walls of cylindrical tubes, into which the ova are received when mature, by a rupture of the enveloping membrane. *Echinodermata* and *most Entozoa*, *&c.*

(5) Similar in form to the last; but the tubes are very dilatable, and when distended with ripe ova are large sacs. *Insects*, *Arachnidans*, *Crustaceans*, *Osseous Fishes*, *&c.*, *&c.*

(6) Similar to the last, except that the ova are developed in masses suspended by narrow pedicles to the walls of the sac, like bunches of grapes. *Cephalopod Mollusks.*

(7) Ova in various stages of maturity developed in ovisacs in racemose branches without any tube, being merely bound down by the peritoneum and a little areolar tissue. *Reptiles* and *Birds.*

(8) Ova developed in ovisacs which are lodged in the meshes of a fibro-areolar stroma, and the whole covered by peritoneum. *Mammals.*

VARIETIES OF OVIDUCTS.

126. The three first named varieties of ovaria require no oviduct, if we except only the special arrangement in frogs, described below (number 2); the ova in other cases being voided directly from the place of original development, or after being discharged into the peritoneal cavity they escape by slits at or near the anus.

(1) Oviduct a simple continuation of the tubular or saccular ovaria, with, in some cases, a special dilatation for the temporary detention of the ova, in order to receive a mucus covering, or to be fecundated by means of sperm previously received into such spermotheca. This variety of oviduct is found in connection with varieties (4), (5), and (6) of ovaria.

(2) Special oviduct with trumpet-shaped orifice at some distance from the ovaria, so that the ova have to pass through the intervening space in the peritoneal cavity; oviduct opening into cloaca. *Frogs.*

(3) Similar to the last, except that the dilated orifice of the oviduct lies near the ovarium, and applies itself around the mature ovum when the latter is about to be discharged. *Reptiles* and *Birds.*

(4) Somewhat similar to the last in its relation with the ovarium, but the two oviducts now called *fallopian tubes* present dilatations in their course, such as one or two *uterine cavities*, in which the ovum is retained in order to establish a secondary connection with the maternal system, and a vaginal canal or organ of copulation. *Mammals.*

127. Structure of the ovarian or unfertilized ovum in oviparous vertebrates. Large amount of vitellus, of which a small portion near the germinal vesicle is lighter and less opake (Discus Vitellinus) and probably corresponds with the whole vitellus of the mamalian ovum. Ovisac. "White" of the egg; membrana putaminis; shell.

128. Characters of the mammalian ovule. Graafian vesicle of two layers, the external being the condensed vascular stroma, the internal a non-vascular ovisac; membrana granulosa; Discus Proligerus. Dimensions of human ovum. Zona Pellucida or vitelline membrane; vitellus; germinal vesicle and germinal spot. Development of the several constituents of the ovum. Changes in the ovum and ovarium preparatory to fecundation. Sympathetic actions of the uterus. Phenomena of "heat" in brutes, and of menstruation in the human female. Analogies between these phenomena; their dependence on the maturation and discharge of unfertilized ova and other correlative ovarian changes. Difference between the corpus luteum of the virgin and that belonging to the condition of pregnancy.

129. Male Sexual Functions.—The only *essential* part of a

male apparatus of generation is an organ for the development of the male or sperm cell, the union of which with the germ cell is an indispensable condition for the formation of a body endowed with *developmental capacity;* accordingly, in very low animal organisms the male apparatus, as simple as that of the female, consists in a mass of sperm cells developed in the general parenchyma and escaping like any other excretion. But in higher beings, parts are superadded for conveying outwardly the sperm cells, the product of the secretion of particular glands called *Testes;* and in very many animals for injecting this product into the vaginal passage of the female by means of an erectile organ of intromission. General view of the whole apparatus in man; sensible characters of the seminal liquid; microscopic characters and development of spermatozoa. Their true nature in relation to the process of fecundation. Reasons for believing that fecundation is accomplished in the outer part of the fallopian tube rather than in the ovary or in the uterus.

130. Development of the Embryo.—Changes in the ovum immediately subsequent to a fecundating copulation and while the ovum is yet in the fallopian tube. Changes of the ovum within the uterus, divided into three stages. (1) Changes prior to the formation of the omphalo-mesenteric vessels. (2) Development of the allantois as a temporary organ of aeration of the blood of the embryo, and representing the only vascular connexion which is established between the maternal system and the embryos of non-placental mammalia. (3) Changes connected with and subsequent to the development of the placenta.

Summary Recapitulation of the Physiology of Generation.

131. A. Assignment of organs in each of the sexes, with a specification of the uses of each part of the complicated apparatus in the human species. B. Explanation of the function; (a) to assign *proximate cause;* any and every formative or developmental operation in a living organism involves the necessity of a threefold condition; (1) a germ or body which is to undergo development; (2) alimentary or nutritive materials at the expense of which the fabric is built up; and (3) certain dynamical stimuli, such as a proper temperature and degree of moisture, &c., &c. But the germ must be endowed with developmental power; and three theories have been maintained with regard to the origin of such germinal capacity; some supposing that it resides inherently in the *germ-cell*, and only requires to be *stimulated* by the seminal liquid, which is thus held to act like heat or any other mere dynamical stimulus (ovarists); others asserting that the developmental capacity resides exclusively in the *sperm-cell;* and that the germ-cell as well as its vitellus is to be regarded as a mass of peculiar nutriment that also

acts as a dynamical stimulus, (*Animalculists*); while a third and now generally accepted theory termed *Epigenesis*, maintains that neither parent furnishes a complete germ, but that the latter is *formed* or *generated* by the conjugation of elements derived from both. This appears to be demonstrated by the phenomena of Hybridity.

(b) To *assign exciting causes*. The developmental capacity with which a duly formed germ is endowed by the act of conjugation between the germ and sperm-cell, is not *manifested* as a *force*, that is, the developmental changes do not take place, except under certain favoring conditions, which are therefore termed *stimuli* or *exciting causes*, of which heat and oxygen are especially necessary. In viviparous animals, these, as well as nutritive materials, are abundantly supplied in the maternal system and *immediately after* fecundation. In warm blooded oviparous vertebrates, a small amount of change takes place in the maternal system, but the ova being soon extruded, the process is arrested for want of the requisite heat until this is subsequently applied either artificially or by natural incubation. In cold blooded ovipara the animal heat of the parent is seldom sufficient and the ova have to be subjected to the influence of solar heat more or less directly.

(c) *Laws*.—In addition to the laws already stated (§ 123), we note the following, which apply to the human species. (1) Ova become mature and are discharged periodically from the ovary, independently of fecundation and coinciding with the catamenia. (2) Fecundation cannot, it is probable, occur in the ovary nor in the uterus, but must be accomplished in the fallopian tube. (3) There is an intermenstrual epoch at which fecundation is almost or quite impossible, namely, ten or twelve days after one menstrual period to within a few days, perhaps, of the next. (4) Fecundation is most likely to occur at or near a menstrual period.

(d) *Final cause*—to perpetuate the species.

(e) *Local and general sympathies*. Morning sickness in the earlier stages of pregnancy; areola around the nipple; kiestine in the urine; and certain later phenomena, the consideration of which belongs to the subject of Practical Midwifery.

II. NUTRITIVE OR VEGETATIVE FUNCTIONS.

132. Necessity for the execution of this class of functions, (1) from the instability of the chemical compounds which constitute the proximate components of the tissues, by reason of which they are constantly undergoing decomposition, and require to be replaced by new material. (2) The more rapid and abundant waste which is one of the conditions of the actions of the organs of animal life, by reason of which no nervous or muscular fibre is equally fit for two successive actions unless it have regained in

the interval what it lost by the first action. The raw material for this restoration is obtained from without in the form of food, and has to undergo a series of changes before it can be used for such purposes; and these several changes are the results of the several nutritive operations. These are (1) Digestion; (2) Chylosis; (3) Hæmatosis; (4) Respiration as a means of absorbing oxygen; (5) Circulation; (6) Nutrition proper; (7) Secretion; (8) Respiration as a means of excreting carbonic acid; (9) other purifying excretions; (10) Calorification.

FUNCTION OF DIGESTION.

133. Definition.—Enumeration of the subordinate acts, namely, (1) Prehension; (2) Mastication; (3) Insalivation; (4) Deglutition; (5) Chymification or action of the stomach; (6) Intestinal digestion or action of small intestine, and (7) Defecation or action of large intestine. Brief statement of the character of each.

134. *Organs concerned* in the execution of this function as exhibited in different classes of animals. (1) Animals without any *special* digestive apparatus, and either absorbing food which is already sufficiently comminuted, or else having their whole tegumentary surface capable of secreting a digestive juice; as the *Sponge tribe*.

(2) Animals without any permanent stomach, which when feeding bend themselves around their food, and make an extemporaneous stomach of their skin: as the *Amœba*, a naked Rhizopod.

(3) The entire animal a mere self-moving stomach with a single orifice surrounded by prehensile tentacula, as the *Hydra*.

(4) Similar to the last, except that the stomach is suspended in a peritoneal cavity. *Actiniform Polypi*.

(5) Stomach with radiating tubes for diffusing the digested matters, and thus increasing the extent of absorbing surface. The tubes are either cœcal, admitting only chylific matter, the excrementitious portion of the food being retained in the central cavity to be ultimately ejected either at the mouth (*star-fish*,) or by a separate anus at the opposite end of the body, (*some annelidans*), or some of the radiating tubes themselves terminate in anal openings (*Pulmograde Acalephans*.)

(6) Alimentary canal of some length, commencing by a mouth at one end, and terminating by a single anus at the other. The tube may be bent upon itself so as to bring the anus near the mouth, as in Molluscans; mouth sometimes organized for suction, but most frequently adapted for cutting, filing, or trituration by means of horny Mandibles and jaws, or by means of a special dental apparatus found in a few invertebrates, and in all vertebrates, except Birds and Chelonian Reptiles; anus guarded generally by a sphincter muscle; intervening tract generally divided into gullet, stomach, small and large intestine. Glandular appendages, as

salivary, gastric, biliary and pancreatic glands secreting fluids that are subservient to digestion. Follicles of Lieberkuhn secreting a protective mucus, and Peyer's glands, organs of depuratory excretion.

135. *Changes of the food effected in the Mouth.* Mastication, its mechanism and its uses; difference in function between the separate classes of teeth. Indications furnished by the character of the teeth in man of his adaptation for an omnivorous diet. Insalivation; sensible and chemical characters of saliva; rate of secretion. Its manifold uses in digestion, and especially its influence in transforming starch into dextrine and grape sugar.

136. *Passage of food into the stomach.* Three stages of deglutition; mode of protecting the Larynx and the posterior nares during the passage of food through the fauces in the second stage.

137. *Chymification or Digestion in the Stomach.* Structure of the stomach in man, and especially the minute structure of its mucous membrane and of the gastric glands; sensible and chemical characters of the gastric juice; circumstances under which it is secreted normally; stimuli which increase or diminish the amount; its effects on alimentary substances substantiated by experiments on artificial digestion; nature of the change which albuminous food undergoes; mechanism of the movements of the stomach and their uses.

138. *Influence of the nervous system on gastric digestion.* This is threefold; (1) in giving rise to the sensations of hunger and thirst which induce to the taking of food; (2) in influencing the secretion of gastric juice as to its amount, and probably also as to its quality, either directly, or indirectly through the sympathies of the stomach with the organ of taste more especially; (3) in determining the movements of the stomach and the passage of food into or from this organ.

139. *Changes of food in the Intestines.* Structure and secretions of the intestinal tube; Brunner's glands; follicles of Lieberkuhn; Peyer's glands; Pancreas and its secretion; Liver and its secretion; influence of these several agents in digestion; twofold nature of the biliary secretion as a digestive agent and a depuratory excretion; changes of the food in the large intestine; movements of the intestinal tube; defecation, &c., &c.

Summary recapitulation of the Physiology of Digestion.

140. (1) Digestion of Albuminous or Proteinaceous food, which by the action of the stomach is converted into a low kind of albumen, being at the same time dissolved. Explanation of this act by Müller, who ascribes the solvent property to muriatic acid, the pepsin being held to act as a dynamical stimulus; Liebig's theory, who compares the phenomenon to one of fermentation, the pepsin acting the part of a ferment. Another stage of the digestive acts accomplished in the intestines; precipitation of the undigested particles of food by the influence of bile, some of the

constituents of which unite with the precipitated mass to constitute the Fæces, the others uniting with dissolved albumen and with fat in emulsion to form chyle. The preliminary processes serve to put the food into more advantageous relation with the gastric juice.

(2) *Digestion of fatty aliments.* Not a chemical but a mechanical change; an emulsion formed under the influence of Bile and Pancreatic Juice in the small intestine; in the stomach they are melted, and if taken as adipose tissue the fat cells are ruptured.

(3) *Digestion of the neutral Hydro-Carbons.* Gum, sugar, &c., very soluble, hence their gastric digestion would appear to be a simple solution. After being absorbed by the Portal veins they undergo a chemical change in the Hepatic circulation, being converted into the fatty elements of Bile, at least in part. *Starch*, on the contrary, being entirely insoluble undergoes a true digestion in the alimentary passages, being converted under the influence of the saliva swallowed with it, into dextrine and sugar.

Final causes of Digestion. A. Special and immediate; (1) to dissolve solid aliments; (2) to convert certain organic compounds into others of similar chemical composition; (3) to separate the insoluble ingredients by precipitation. B. More remote final causes of digestion, or sources of demand for food; (1) to build up the fabric from the condition of infancy to that of maturity; (2) to supply the constant waste connected with ordinary nutrition; (3) to supply the more rapid waste connected with the action of the muscular and nervous apparatus; (4) to furnish fuel for respiratory combustion; (5) to supply extraordinary expenditures such as occur in pregnancy, lactation, hæmorrhages, profuse suppuration, &c., &c. For one of these purposes, that namely of maintaining the animal temperature, the nonazotized aliments, whether fats or neutral Hydro-carbons will suffice. For all the other uses we require plastic albuminous compounds.

DIFFERENT DIETETIC QUALITIES OF FOOD.

141. (1) *Digestibility* or facility of undergoing digestion, measured by the mean time of digestion in *a given amount of gastric juice.* But of two substances, one which is less digestible intrinsically may yet be soonest digested in the living stomach, because it may by its sapidity or stimulating character provoke a more abundant supply of gastric juice. Intrinsic digestibility dependent chiefly on the physical properties of the food; actual digestibility largely dependent on the physiological relations of the food with the living system..

(2) *Nutritiousness.* Absolute nutritiousness measured by the percentage of plastic or proteinaceous matter in the food. But the virtual quality depends on the amount duly digested and assimilated. Hence that which is absolutely richest in nutriment may be the least nutritious in point of fact because the least

digestible. Hence too the actual nutritiousness of the same elements varies according to the state of the digestive organs.

(3) *Calorifacient property.* The absolute capacity measured by the percentage of alimentary fuel, that is of free carbon and hydrogen, which food contains. But some hydro-carbonaceous compounds being less easily digested than others, may be virtually less calorifacient though absolutely richer in combustible elements, since these must be digested before they can be burnt off.

(4) *Sapidity.* Different kinds and degrees of this property; highly important with reference to the actual digestibility of food, by reason of the sympathy between the organ of taste and the stomach. Hence the value of indirect condiments. Direct condiments; danger of using them too freely.

(5) *Irritating property.* That which causes the morbid condition termed Irritation; for example the gastralgia or enteralgia caused by green acid fruit, cabbage, &c. Some articles of diet as *mucilage, &c.*, are entirely devoid of this quality and are even positively soothing.

(6) *Stimulating property.* Or the power of stimulating the system irrespective of the excitement that may be due to defective digestion, or to excess of nutrition or to local irritation. Phenomena remotely analogous to the effects of alcoholic drinks. Lobster, Crabs, &c., sometimes stimulate in this way.

ALIMENTARY PRINCIPLES.

I. Class—Aliments which are calorifacient but aplastic.

142. (1) *Gum*=$C_{12}\ H_{11}\ O_{11}$. (2) *Sugars*; cane sugar=$C_{12}\ H_{11}\ O_{11}$ sugar of milk=$C_{12}\ H_{12}\ O_{12}$ and grape sugar=$C_{12}\ H_{14}\ O_{14}$. (3) *Starch* =$C_{12}\ H_{10}\ O_{10}$. (4) *Lignine* or *woody fibre*=$C_{12}\ H_{8}\ O_{8}$. (5) *Pectine* and *Pectic acid*=$C_{12}\ H_{8}\ O_{10}$. (6) *Vegetable acids*, as acetic, citric, tartaric, malic and oxalic acids. (7) *Oily* or *fatty matters*, as oleine, margarine, stearine, &c. (8) Alcoholic principle=$C_{4}\ H_{6}\ O_{2}$.

II. Class—Plastic or nutritive alimentary principles.

143. (1) *Proteinaceous principles.* Three varieties all of which are found in both the animal and vegetable kingdoms. *Proteine*, artificially prepared=$C_{40}\ H_{31}\ N_{5}\ O_{12}$. *Fibrine*=10 Pr.+P+S. *Albumen*=10 Pr.+P+S_{2}. *Caseine*=10 Pr.+S.

(2) *Gelatinous principles.* Two varieties, *Collin* or *Gelatine*

proper, and *Chondrin*. Sensible and chemical characters; doubtful dietetic qualities.

(3) *Alimentary principles contained in the juice of muscular flesh.* As Kreatine; Kreatinine; Inosinic acid; Lactic acid, &c., which are probably both condiments and elements of nutrition.

III. Class—Inorganic alimentary principles.

144. (1) *Water.* (2). *Saline alimentary principles.* Chlorides of sodium and potassium, alkaline phosphates, sulphates, lactates and carbonates, all of which are soluble, and phosphates of lime and magnesia which are insoluble. Inasmuch as iron is a necessary ingredient of the blood, some of its salts must be contained in our food; otherwise disease ensues, which can only be relieved by the administration of ferruginous tonics.

145. Changes of food produced by the different culinary process. (1) *Boiling;* difference of effect according as the meat is plunged into water already boiling, or into cold water which is gradually raised to the boiling temperature. (2) *Roasting.* (3) *Broiling.* (4) *Baking.* (5) *Stewing.* (6) *Frying.*

compound aliments.

I. Animal Food.

146. (1) *Mammalia* furnish a number of solid tissues for the food of man, while the milk of a few species, especially the cow, is also employed. The most important is *muscular flesh streaked with fat*, containing fibrine, albumen, gelatine, and the sapid juice. Bones, fibrous tissue, cartilage, brain, liver, kidneys, pancreas, thymus gland, stomach of ruminants, (*tripe*) and skin are likewise used. Notice of the principal kinds of meat, beef, veal, mutton, lamb, pork fresh and cured, &c. &c. Composition and dietetic qualities of *cow's milk;* composition and dietetic qualities of *cheese.*

(2) *Birds.*—Muscular flesh, viscera and eggs; dietetic qualities varying with the species.

(3) *Reptiles.*—Eggs and flesh of several species of the Chelonia highly esteemed, but they are rich, stimulating and often irritating.

(4) *Fishes.*—Smaller species eaten whole; of the larger, all the viscera except the ovaria (*roe*) are rejected; dietetic qualities varying with the species; very irritating, or even poisonous when not fresh.

(5) *Crustaceans.*—Lobster, crab, shrimp, prawn, &c., have a white firm flesh difficult of digestion; apt to irritate, highly stimulating.

(6) *Molluscans.*—Oysters, clams, snails, &c., &c., nutritive and stimulating, but often difficult of digestion.

II. Vegetable Food.

147. (1) *Farinaceous or amylaceous vegetables.*—Two varieties; (a) the *cereal grains*, as wheat, rye, barley, &c.; composition of wheat flour. Unfermented bread. Fermented bread; mode of preparation; liability to turn sour, &c. Why stale fermented bread is more wholesome than hot or fresh bread. (b) The *leguminous seeds*, as peas, beans, &c., containing besides starch, a large amount of legumin (vegetable caseine), but deficient in some of the important saline principles. (c) Under the head of farinaceous aliments ought to be included some *tubers*, such as the Irish potato, because of the large amount of starch which they contain.

(2) *Oily seeds.* Almonds, hazelnuts, filberts, walnuts, &c., &c.

(3) *Fleshy fruits.* Apples, peaches, plums, pears, apricots, cherries, &c., &c., &c.

(4) *Vegetable roots and tubers.* Turnips, parsnips, carrots, beets, &c., &c.

(5) *Buds and young shoots.* Onions, shallots, asparagus, &c., &c.

(6) *Leaves and leaf stalks.* Cabbage, cauliflower, broccoli, lettuce, &c., &c.

(7) *Fungi* or *mushrooms.* Most species poisonous, even the edible species are difficult of digestion and when digested are very stimulating.

III. Liquid compound aliments.

148. (1) *Mucilaginous drinks*, or solutions of many of the varieties of *Gum;* demulcent and calorifacient; but may turn sour, especially when flavored with sugar. Gum Arabic; slippery elm; flaxseed; barley water; Mexican seed; toast water; varieties of gruel.

(2) *Aromatic or astringent drinks.*—Tea; its composition and physiological effects. Coffee; chocolate; cocoa; broma.

(3) *Acidulous drinks.*—Lemonade; tamarind water; strawberry acid, &c., &c.

(4) *Animal teas*, containing only the *juices* of meat separated from the flesh previously finely divided, by long simmering in water kept a little below the boiling point, in order to avoid a solution of the gelatine; as beef tea, chicken water, &c.; sapid, easily absorbed and probably nutritious.

(5) *Soups* have dissolved gelatine for their basis, and therefore the flesh must be *boiled.* Portable soup or *stock;* dietetic qualities of soups.

Sympathies of the Digestive Organs.

149. *State of the system coincident with the feeling of natural*

hunger and thirst. Debility and diminished action of all the organs except those concerned in absorption, which process being physical and dependent on the state of the blood-vessels as to fulness, is more actively performed. Hence danger of exposure to malaria on an empty stomach. Diminution of bodily temperature; diminution of secretions; but the gastric and salivary glands are in a condition to respond actively on the first application of a normal stimulus.

150. *Phenomena of prolonged fasting and starvation.* May be conveniently divided into three stages or degrees. (1) Intense feeling of hunger; sense of great debility, which is, however, mainly sympathetic. (2) Dragging pain at epigastrium; dryness of throat and fauces; acidity of saliva; urine scanty and acrid; redness of the eyes, &c., &c. (3) Phenomena which precede death, varying according as the demand is most urgent for plastic or calorifacient food. In the former case *furious delirium* succeeds the phenomena above mentioned. In the latter the proximate cause of death is depression of the animal temperature, and is attended by a passive quietness and torpor in striking contrast with the fierce excitement characteristic of the death from want of plastic nutriment.

151. *Physiological effects of healthy digestion.*—Feeling of satisfaction and increased strength; glow at the epigastrium radiating over the system; slight increase in the heart's action and the energy of respiration; organ of taste loses some of the keenness of its susceptibility; deglutition becomes more difficult; limit to the quantity of saliva and gastric juice.

152. *Physiological effects resulting from the habitual use of aliments defective in quantity or quality.* See Carpenter's Elements, § 416 to § 421.

153. *Physiological effects of overloading the stomach.* Sensation of painful distension; nausea; torpor; chilliness, or perhaps fever; liability to irritation, which is soonest relieved by an emetic of warm water, if the offending substance had not passed the stomach, or by an active purgative if it had.

154. *Physiological effects resulting from the frequent or habitual digestion of more food than is needed for the wants of the system.* —These vary according as the excess consists, (1) of albuminous or plastic food. (2) Of fat, or substances convertible into fat. See *Carpenter, loc. cit.*, § 421—§ 426.

VARIETIES OF DIET AS SUITED TO DIFFERENT CLASSES OF INVALIDS.

155. (1) *Cooling and abstemious regimen.* Often required in cases of fever, &c.; acidulous drinks; but their irritating qualities must be guarded against wherever there is liability to gastric or intestinal irritation.

(2) *Soothing or demulcent diet;* required when the alimentary, urinary or respiratory passages are irritated or inflamed; such as the different *mucilaginous* drinks. See § 148.

(3) *Light plastic diet,* which shall tax the digestive powers but little, and yet subserve nutrition. Animal teas; water crackers; stale bread; boiled milk, &c.

(4) *Ordinary diet.*

(5) *Generous or rich diet.*—Boiled eggs; tender and juicy meat broiled or roasted; oysters, especially if roasted; porter or ale; for persons reduced by profuse suppuration, loss of blood, lactation, &c., who yet have good powers of digestion.

(*For a full exposition of the proper dietetical rules as to the most suitable times of eating, the quantity to be taken at a meal, the character of the different meals, the condition to be observed before and after eating, and the due regulation of the bowels, the students are referred to the admirable treatise of Andrew Combe on "Digestion and Dietetics."*)

FUNCTION OF CHYLOSIS AND LYMPHOSIS.

156. Definition and enumeration of organs concerned.—(1) Intestinal villi, containing each a loop of lacteal vessels and a group of absorbent cytoblasts, which during absorption become developed into cells. (2) Lacteal and other lymphatic vessels with their appended *glandulæ* especially the *mesenteric.* See Carpenter's Elements, § 489 to § 505.

157. *Explanation of the Function.*—The term *chylosis* expressive of a double act; (1) the passage of soluble matters from intestinal canal into the lacteal vessels. (2) The transformation of the digested but yet unvitalized matters into *living chyle.* So also for *lymphosis.* Notice of the phenomena exhibited during the execution of the function by different vessels, as (1) by the lacteals. (2) By other lymphatic vessels. (3) Properties of chyle and lymph. (4) Office of the lacteal and lymphatic vessels and glands. (5) Absorption by the veins. See *Kirkes & Paget, under these several heads,* as also *Carpenter's Elements,* §§ 522 and 523, for the phenomena of absorbtion from the cutaneous and pulmonary mucous surfaces.

Thus the proximate cause of the transformation of intestinal chyme into chyle and of the formation of lymph from the redundant plasma effused into the interstices of tissues would appear to be the inherent developmental capacity of the absorbing *cytoblasts* or *cells,* whether seated externally to the absorbent vessels as in the intestinal villi, or forming a sort of *spheroidal epithelium* for the intra-glandular lymphatics. In both cases the development is at the expense of the material which is converted by this

very act into organised lymph or chyle. The exciting causes are a due supply of chyme or of plasma, a suitable state of the blood circulation in the surrounding parts, and a proper state of innervation. Little or nothing is known of the special laws of this function. Final cause, to elaborate the materials for the development of blood.

158. The explanation of the physical part of the process, namely, the act of absorption, involves the consideration of the relations of the absorbed matters, first, to the porous barrier through which they pass, and secondly to the liquid already existing on the other side of such barrier. (1) Force of imbibition proportional to the degree of attraction between the particles of the liquid to be absorbed and those of the barrier or absorbing medium; also dependent on the size of the capillary pores being greater when these are minute and numerous than when the texture is coarser; greatly increased by an elevation of temperature. (2) Influence of a second liquid on the other side of the barrier; (a) when both liquids have an attraction for the interposed barrier, but no affinity of mixture for each other; (b) when the two liquids not only have an attraction for the barrier but also a tendency to mix with each other. Phenomena of Endosmosis and Exosmosis; different rate of diffusibility in water of different salts and organic products held in solution. Thus the *direction* of the most energetic current is determined by the *attractive power of the septum* for one or the other liquid, while the diffusive power of the liquids through each other will help to determine its *force*. The *energy* of the movement also influenced by the side of the membrane turned towards water, the passage of which towards a denser liquid being much more energetic when the internal mucous surface of a hollow viscus is in contact with the water than when its position is reversed. Circulation of fluid in the absorbing vessels not only promotes the diffusion of that which has been absorbed but also increases the rapidity of absorption.

FUNCTION OF HÆMATOSIS.

159. Definition.—Sensible characters of Blood; microscopic analysis; rough chemical analysis effected by spontaneous coagulation; formation of buffy coat shown to be a vital process of organization; conditions influencing coagulation; circumstances favoring the production of the buffy coat; (a) physical conditions, as diminished specific gravity or else diminished viscidity of the liquor sanguinis, allowing the corpuscles to subside in a measure before coagulation commences, or slowness of coagulation, the density and viscidity of the blood being normal; (b) vital conditions, such as an increased attraction of the corpuscles for each other manifested by their uniting in piles, which subside more readily than the individual corpuscles, as exemplified in inflammatory blood.

Description of the several organized agents found in the blood; quantitative chemical analysis; special account of each of the ingredients.

160. History of the development of blood corpuscles; (1) temporary blood cells formed in the early embryo before either chyle or lymph appears to be soon superseded by (2) the true discoid blood-cells developed from lymph and chyle corpuscles; development of liquid fibrine commensurate with that of the corpuscles; vital properties and uses of the blood.

161. Thus blood differs from chyle (1) in the maturity of a large majority of its floating cells, as indicated by their discoid shape, the incorporation of new organic principles, such as globuline and hæmatine, and by their apparent relations with the respiratory function; (2) in a larger relative proportion of fibrine and its more perfect elaboration, and (3) by the presence of a large amount of oxygen and nitrogen derived from the atmosphere, and of carbonic acid resulting from the combustion of alimentary fuel, or from the disintegration of the tissues. Conjectural opinions as to the agency of the spleen, thymus and thyroid glands in the process of hæmatosis. See *Kirkes and Paget*, Chap. XII. on "*Glands without ducts.*"

PHYSIOLOGY OF THE CIRCULATION.

162. Necessity for such an act; specialization of a circulatory apparatus in all but the protozoa and lower radiata; review of the varieties exhibited in the whole animal series. See *Carpenter, loc. cit.* § 540 to § 567.

163. Statement of the leading phenomena of the act as executed by the human being; positive and experimental demonstration. Systemic and pulmonary circulations, each being a segment of the whole circle and the complement of the other; local circulations, or the circulation through individual organs, are generally mere offshoots from the general systemic circulation.

164. *Action of the heart.*—Mechanism; rythm; phenomena coinciding with the systole and diastole; action of the valves; frequency and force of the pulsations. *Proximate cause.*—Inherent contractility of muscular fibres excited by an intermittent or alternating stimulus, or else inherently rythmical.

165. *Action of the arteries.*—Structure: uses of elastic coat; proofs of muscularity and uses of muscular endowments; phenomena and explanation of the pulse; force of the blood in the arteries.

166. *Action of the capillaries.*—Structure and other anatomical characters of the individual vessels; form and closeness of the capillary network dependent on the arrangement of the proper elements of the tissues and on their functional activity; micros-

copic appearances of the capillary circulation; effects of change of calibre on the rapidity of the circulation; variation in the direction and rapidity of the circulation independent of change of calibre and of any alteration in the vis a tergo; physiology of active local determinations of blood; influence of the nervous system on the capillary circulation partly direct and partly indirect. See Carpenter, loc. cit. § 589 to § 605.

167. *Action of the veins.* Structure and properties of the venous tunics. Rate of motion in the veins. Forces operating on the venous system, auxiliary to the vis a tergo. General considerations with reference to the whole circulation; such as time expended in the whole round, and the different ways of arriving at a reliable estimate. Peculiarities of the circulation through the liver (*portal* circulation), brain, lungs, kidneys, and erectile organs.

168. *Final causes or uses of the circulation.* (1) To distribute nutritive plasma and oxygen. (2) To eliminate impurities with which the blood becomes charged in going its round, by distributing it to the different depuratory glands, such as the lungs which remove carbonic acid, the liver, which separates liquid hydro-carbonaceous matter, and the kidneys which excrete effete azotized matters in the form of urea and uric acid. (3) To maintain uniformity of composition of the blood by mixing together the different portions which have been variously altered in the different local circulations.

PHYSIOLOGY OF RESPIRATION.

169. *Definition.* A double function for the ingestion of oxygen and the excretion of carbonic acid and some other gaseous impurities, so as to maintain the purity of the blood. Sources of demand for oxygen threefold. (1) To subserve the disintegration of such parts of the tissues as have fulfilled their term of life, and are to be removed, but are so situated that they cannot be thrown off in mass. (2) To stimulate the functional activity of the muscular and nervous systems, by subserving a more rapid and energetic disintegration. (3) To maintain in warm blooded animals the requisite combustion of alimentary fuel. Sources of supply of the carbonic acid exhaled in respiration are exactly correspondent. Proofs of the performance of this function and of its primary importance, especially as respects the uninterrupted elimination of carbonic acid, the retention of which is termed *asphyxia* and is promptly fatal.

170. Varieties of respiratory apparatus in the animal series arranged according to the two classes of water-breathing and air-breathing animals. See *Carpenter, loc. cit.* § 653 to § 674. Structure of the human lungs.

171. Mechanism of respiration in man; inspiration; expiration; abdominal, inferior and superior costal type of respiration. Ex-

citing cause of the action of inspiratory muscles; necessity for the activity of a nervous centre, and of both afferent and efferent nerves. Effect of these movements; breathing air; complemental air; reserve air; residual air; vital capacity of respiration, how affected by age, stature, and weight. Females have only half the capacity of males of same age. Force of inspiration and expiration.

172. *Chemical phenomena of respiration.* Composition of atmospheric air. Different effects produced by animal and vegetable life on the constitution of the atmosphere see § 54, p. 22. Composition of the gas held in solution by fresh water amounting to about $\frac{1}{2\frac{1}{5}}$th of the bulk of the water. Sea-water holds only about $\frac{1}{3\frac{1}{5}}$th of its bulk of gases. In each there is about 33 per cent. of oxygen, with from 2 to 10 per cent. of carbonic acid. Changes produced by respiration on the air taken into the lungs. (1) Of temperature. (2) Increase of the per centage of carbonic acid and loss of a portion of its oxygen. (3) Increase of its watery vapour. (4) Acquires some volatile organic ingredients.

Circumstances influencing the amount of carbonic acid exhaled in a given time. (1) Age. (2) Sex. (3) Respiratory movements. (4) External temperature. (5) Purity of the inspired air. (6) Period of the day. (7) Food. (8) Alcoholic drinks. (9) Bodily exercise. (10) Sleep. (11) Muscular development. (12) Barometric pressure.—Changes in the blood coincident with those in the aerating medium. (1) Assumption of arterial colour. (2) Increase of temperature by 1° or 2° F. (3) More perfect elaboration of fibrin. (4) Increase of oxygen and disappearance of a nearly equivalent amount of carbonic acid. Mutual connection between these changes with their explanation or *theory of respiration.* Theory of LAGRANGE and HASSENFRATZ, proved by the experiments of MAGNUS.

173. Application of the physiology of respiration and circulation, to the explanation of the phenomena and method of treating ASPHYXIA. See KIRKES and PAGET, and CARPENTER, *loc. cit.*

PHYSIOLOGY OF CALORIFICATION.

174. Definition.—The animal kingdom divided into two groups with reference to their relations to heat; namely into *cold-blooded* and *warm blooded animals.* Difference between the two as to their respective ranges, (1) of bodily temperature, and (2) of external temperature.

175. Source of the heat generated by warm-blooded animals—Inductive proof, as derived from a comparison of all the instances in which living organisms give out heat as; (1) Germinating seeds. (2) Flowering plants at the period of inflorescence. (3) Insects when in active exercise become for the time warm-blooded, being naturally cold-blooded. (4) Birds and mammals generating heat

in proportion to the vigour of their respiration. Other combustibles, however, besides carbon are burnt or oxydized in the system, as hydrogen, phosphorus, sulphur, &c. Mechanical causes also cooperate; and very probably the manifestation of the nervous force is attended with an elevation of temperature irrespective of the chemical changes which occur at the same time.

176. *Agencies influencing the production of animal heat.* (1) Age; production at its minimum at birth as shown by an infant's incapacity to resist external cold without a considerable lowering of the bodily temperature. Shown also by the greater mortality among infants in winter than in summer. The calorific faculty becomes more vigorous with the advance of years to about thirty-five or forty, when it remains stationary for a time, to again become more feeble in old age. (2) Influence of *seasons.*—Summer, constitution lessens the power of producing heat and vice-versa. (3) *Influence of the momentary application of heat and cold*, the reverse of their long-continued operation. (4) Effects of *climate*, analogous to those of season. Paradoxical effects occasionally observed in natives of warm climates, when exposing themselves for the first time to the rigours of a cold climate and plausible explanation of the phenomena by W. F. Edwards. (5) Effects of refrigeration in dry and humid air—(6) effects of refrigeration in air at rest and air in motion—(7) influence of food—Chossat's experiments with birds totally deprived of food and drink—(8) alcoholic drinks depress the heat producing faculty except in certain cases—(9) sleep—(10) exercise—(11) muscular development—(12 time of day—(13) purity of the air—(14) health and disease—by disease, adults may be reduced to the condition of infants, quoad this function. Some persons constitutionally so, though not otherwise unwell, as shown by their habitual sensations, and chiefly by the actual reduction of the bodily temperature on exposure to external cold—(15) means of restoring heat when the animal temperature is depressed—(16) means of reducing heat when it is generated in excess as in fevers, &c.

PHYSIOLOGY OF NUTRITION.

177. Distinction between *development*, *growth*, and *simple maintenance* or *nutritive reparation.* In each the prominent feature is the incorporation with the existing organism of a new material, which though originally dissimilar, is, in the very act of incorporation, *assimilated* to the organism—all, therefore, are merely different modes of manifesting the same fundamental life-force which is variously termed *plastic force*, *force of nutrition*, *germ power*, *germinal capacity*, *developmental capacity*, *nisus formations*, *&c.*, *&c.* Conditions which determine the manifestation of this force in each of the three modes just named.

178. Phenomena of nutrition exhibited by *hairs*, *teeth*, *epithelial*

cells, &c., where nutrition appears to go on unchecked by any process of disintegration up to a certain epoch, when the *part having reached its appointed term of life* dies and is thrown off in mass, to be replaced by a new part going through the same stages of development from a germ, growth and spontaneous death. The fangs as well as the crowns of the permanent teeth die in this way and drop out in old age. But the fangs of deciduous teeth undergo a *degeneration*, the result of which is plainly visible, there being no compensating deposit.

179. Inference drawn from these cases as to the interstitial degeneration constantly going on in those tissues which are so situated as that the dying particles can only be removed by absorption, and the nature of whose functions precludes the possibility of their dying in mass without manifest injury to the system. Incidental proof of such disintegration in the muscular and nervous structures. In all such tissues we find on their elementary fibres nuclei or germinal centres which are apparently the seat and agents of the force of nutrition, so that the nutritive deposit which is constantly taking place, resembles the act of original development in the manner in which it is accomplished.

180. The *proximate cause*, therefore, is the fundamental *germ force*, the exercise of which in the way of simple nutrition, presupposes the molecular disintegration and removal of some of the old particles, which is constantly taking place in accordance with a universal and fundamental law of life prescribing a limited duration to every constituent organized cell or other elementary structural component of animal and vegetable tissues. Other exciting causes common to all three modes of nutrition, as (1) a proper condition of the blood—(2) a regular and not too distant supply of such blood—(3) a certain degree of nervous influence, which, however, is not an *essential* condition. (4) Healthy state of the part which is to undergo nutrition. In all cases too, other things being equal, the energy of nutrition is proportional to the functional activity of the part. Hence parts fulfilling mere physical uses undergo but little disintegration, &c.

PHYSIOLOGY OF SECRETION.

181. Definition.—Varieties of secreting apparatus. (1) Independent and isolated cells, like those of chyle, lymph and blood. (2) *Epithelia* or membraniform aggregations of independent cells. (3) *Follicles* or pouches which were originally cells that after undergoing enormous dilatation opened upon some contiguous mucous membrane and remained as a permanent structure, while its progeny, the product of endogenous development are constantly detached and discharged through the mouth as a secretion. (4) *Glands*—an assemblage of minute follicles, whose ducts unite in various ways so as ultimately to open by one common outlet.

182. Mechanism of secretion. It is, therefore, identical with the act of nutrition or development of epithelial cells which are detached and discharged in mass—Classification of secretions into *recrementitious*, *excrementitious* and *mixed*, or into *protective* secretions, as mucus, synovia, &c., and *special*, as bile, saliva, urine, &c.

BILIARY EXCRETION.

183. Minute structure of the human liver, especially with reference to the arrangement of the portal venous plexus and the plexus of minute bile ducts *within* the substance of the elementary lobules of the liver—biliary or hepatic cells forming, according to LEIDY, a spheroidal epithelium to the minute radicles of the biliary ducts.

184. Chemical characters of human bile—sensible characters—conditions of the secretion—peculiarities of the blood of the portal vein as compared with ordinary venous blood, being darker, less heavy, and not capable of being rendered bright by contact with oxygen, salt, or atmospheric air. It contains only about half the ordinary proportion of fibrine, which is also less perfect; has less albumen but more red corpuscles and nearly twice the amount of fatty matter. These differences probably dependent on the action of the spleen as an organ of hæmatosis. Sugar found in blood of portal vein during digestion, but none in that of the hepatic veins. Quantity of bile considerably increased by non-nitrogenous diet—artificial conversion of saccharine substances into fatty principles by the action of bile.

185. Mechanism of the secretion of bile and of its passage into gall-bladder—into the duodenum—average quantity per diem—uses of bile as an excretion vicarious with that of the lungs. Hence frequency of liver diseases in tropical climates. Uses of bile as a digestive agent and as a natural purgative.

CUTANEOUS EXCRETIONS.

186. Anatomical characters of the excretory apparatus connected with the skin. (1) Sudoriparous or sweat glands—(2) sebaceous or oil glands.

187. *Action of the sweat glands.*—Estimate of their number and the length of tubing—sensible and chemical characters of sweat; has from 1 to $1\frac{1}{2}$ per cent. of solid matter partly saline and partly a proteine compound, which may amount to as much as 100 grains in a day. *Insensible perspiration.* How shown to depend on simple evaporation; estimate of the amount of water exhaled by the skin and lungs in a day from 1 to 5 pounds, or about 3 pounds on an average, of which $\frac{2}{3}$ are furnished by the skin; regulating action of the kidneys, which act vicariously with the skin in regard to the excretion of water, and also of nitrogenous

matter to some extent; hence danger of Renal disease when excretory action of the skin is completely arrested; importance of the skin as an aerating organ.

188. *Action of the sebaceous or oil glands.* Oily nature of the secretion—uses. Hence *chapping* of the skin caused by influences which disturb the secretion; meibomiam glands; ceruminous or wax glands.

URINARY EXCRETION.

189. Varieties of urinary apparatus; in insects—molluscans—fishes—reptiles—birds and mammals. Minute structure of the human kidneys with the malpighian bodies and renal portal system of vessels.

190. Condition of the secretion; action of the vascular capillary tufts of the malpighian bodies, as waste gates for drawing off from the blood the watery constituents of the urine holding salts in solution. Action of the epithelium cells of the uriniferous tubes in secreting the organic ingredients of urine from the blood of the Renal Portal system. Large size of the Renal artery and vein; consequent rapidity of the secretion. Rapidity of the passage of certain salts from the stomach to the bladder. Mechanism of the action of the bladder.

191. Sensible and chemical characters of the urine—*urina sanguinis—urina potûs—urina cibi—summer and winter urine*—chemical composition. (1) Urea=$C_2 H_4 N_2 O_2=C_2 NO+NH_3+HO$=hydrated cyanate of ammonia exists, in the proportion of about 15 parts in 1000 of urine. Influence of age, sex, exercise, and diet on this percentage and on the absolute amount excreted in a given time. Derived partly from unassimilated nitrogeneous food and partly from the normal disintegration of the tissues—(2) *Uric Acid*=$C_{10} H_4 N_4 O_6$. Hence Uric Acid+4 $(HO)+O_6=2$ equiv. Urea+6 $(CO)_2$. (3) *Hippuric Acid*=$C_{18} H_8 N O_5+HO$. (4) Mucus, colouring matter and animal extractives, containing kreatine, kreatinine, &c. (5) Lactic acid, the existence of which is denied, however, by Liebig, who describes a peculiar organic nitrogenous substance that unites with zinc and forms a compound mistaken for lactate of zinc. (6) Saline ingredients: chloride of sodium and potassium, sulphates and phosphates of soda and potash; phosphates of lime and magnesia. Origin of the alkaline sulphates and phosphates (which are found very sparingly in food) from the normal disintegration of the nitrogenous tissues, and especially the nervous tissues so far as the phosphates are concerned. Origin of the earthy phosphates—(7) water—(8) accidental ingredients.

192. Proof of the pre-existence in the blood of the chief con-

stituents of urine. Consequences of this condition of the blood when the eliminating action of the kidneys is arrested. Two classes of diuretics, (1) those which merely increase the watery exhalation, as most vegetable diuretics—(2) those which exert a solvent action on the animal solids and thus increase the amount of animal matter excreted by the kidneys, such as alkalies and salts with alkaline bases united with vegetable acids.

EXCRETORY ACTION OF THE INTESTINAL GLANDULÆ.

193. (1.) Action of the follicles of Lieberkuhn in secreting a protective mucus, which, after fulfilling its local office is destined to be thrown off.

(2.) Action of Peyer's glands in excreting putrescible matter from the blood. Inferential proof of this doctrine.—See *Carpenter's Elements*, &c.

GENERAL SUMMARY OF THE EXCRETING PROCESSES.

194. Necessity for the excretion of effete matters more urgent than for the ingestion of fresh material. Two processes involved in every act of excretion; (1) formation of the product to be excreted, and (2) elimination by some depuratory gland of the excretory matter thus formed. Character of the process by which the characteristic products for excretion are formed. Notice of three kinds of spontaneous decomposition which lifeless animal matter may undergo under different circumstances.—(1.) *Putrefaction*, or a very rapid decomposition, favoured by the retention in the decomposing mass of the first formed products, and characterized by the union of the different combustible elements with each other, forming sulphuretted, carburetted and phosphuretted hydrogens.—(2.) Complete oxydation of all the combustible elements, which requires a long time, and in order to prevent putrefaction a depression of temperature—(3.) a change of an intermediate degree in which a good deal of carbon and hydrogen are burnt off, while a portion of these combustibles unite with each other and with nitrogen and oxygen to form *fatty compounds*, *cyanate of ammonia*, *lactic acid*, &c. The conditions favorable to this process are a moderate temperature and the removal of the products as fast as they are formed, inasmuch as they are themselves liable to undergo putrefaction and to impart this tendency to the whole mass. These compounds are just those which are exhaled from the system by the action of the depuratory glands.

195. Uses of the excretions—(1) to purify the blood of the products of the disintegration of the tissues—(2) of those resulting from the disintegration of unassimilated food—(3) to carry off abnormal products, whether introduced from without or generated by a

morbid process in the system itself. Illustrations of each of these uses with reference to each of the principal excretions.

GENERAL SUMMARY OF THE ORGANIC FUNCTIONS.

196. Definition. Functions that have reference more or less directly to the *formative* operations, by which the ovum is first prepared and then developed into the fœtus, (*functions of generation*), and by which the several tissues gradually assume their perfect condition as to form, density, size and vital powers, and subsequently maintain the same general features which by development and growth they have once acquired, (*nutritive functions.*) Enumeration of the special acts included in each of these classes of functions and notice of the essential character of the several acts, all performed under the operation of one common germ force, so far as any vital force is concerned. By the act of *epigenesis* each germ is provided with enough of the germ power to carry it through all the developments characteristic of the species, and then to maintain its existence (if no disturbing causes intervene), for a term of life appropriate to such species. Three fundamental and essential conditions for the simplest manifestations of vitality, namely, (1) an organism endowed with germ force—(2) nutritive or assimilable materials expended in the acts of development, growth, or simple nutrition—(3) the presence of the disintegrating agent oxygen, aided by some of the dynamical stimuli, heat, electricity, light, &c. In lower organisms on the removal of the conditions belonging to this class vital manifestations are suspended, but vital power is retained in a dormant state to be again awakened into activity on a renewal of the stimuli. But in higher animals not only do vital manifestations cease, but the power of renewing them is rapidly lost, owing to the spontaneous chemical changes which promptly take place in the complex and highly putrescible fluids and solids as soon as the chain of vital actions is broken.

197. The organic functions of animals identical as to their *essential* conditions with those of plants. But animals use their peculiar powers to assist in bringing both nutritive materials and the agents of dynamical stimulation into advantageous relation with the organs concerned in the nutritive acts so as to make the organic functions *incidentally* dependent on those of relation—illustrations derived from each of the organic functions of man. Another final cause of the connection between the nervous system and the apparatus of nutritive life is to establish a chain of sympathies between the different parts of the latter, so as to insure harmony of action and symmetry of result. But, thirdly, the nervous force appears in some cases to afford a stimulus which supersedes the necessity of extreme alterations in the quantities of external stimuli, for which office it is well adapted by reason of

its remarkable correlations with some of the physical forces. Illustrated by the cases in which a nervous influence determines changes in the *quality* as well as the *quantity* of a secretion.

198. Such being the scope of the nutritive operations in man, we need, in order to their full elucidation, to be acquainted (1) with the natural characters of the organism, which is the object of anatomy, human and comparative—(2) with those of nutritive matter, both in its crude state prior to digestion and assimilation, (*materia alimentaria*), and after it has been assimilated to chyle and blood,(animal chemistry)—(3) with the influence of heat, light, electricity, &c., as agents of vital stimulation—(4) with the mode in which the nervous system establishes the sympathies of organs —(5) with the influence of the nervous force as a source of vital stimulation in lieu of the physical forces of heat and electricity—(6) with the laws and final causes of the processes, as they are actually performed.

B.—ANIMAL FUNCTIONS

OR

FUNCTIONS OF RELATION.

FUNCTIONS OF THE NERVOUS SYSTEM.

199. Review of the general anatomy of the two elementary structures of the nervous system, namely, nerve fibres and the vesicular nervous substance as found in the ganglionic centres of the nervous system. Modes of connection between the two. Modes of peripheral termination of nerve fibres.

Evidence furnished by comparative anatomy as to the separate offices of the two elementary nervous structures. (1.) Analysis of the *animal* acts executed by the higher radiata with a distinct nervous system. (2.) Notice of three grades of development of the molluscan type of nervous system as exhibited respectively by the *Ascidian Tunicata*, by the *Lamellibranchiates*, and by the *Cephalopoda*, compared with the mode in which they severally execute their animal functions. (3.) Notice of the articulate or homogangliate type in its several grades of development—comparison of the actions of a perfect centipede with those executed by the decapitated trunk, or by separate segments, so as to exhibit the difference in function between the cephalic and the abdominal ganglia. (4.) Respiratory and stomato-gastric ganglia of molluscans and articulates.—See *Carpenter—loc. cit.*—§ 848 to § 867.

GENERAL PHYSIOLOGY OF NERVE FIBRES.

200. Two classes of nerve fibres. A. *Afferent fibres*, conduct-

ing the nervous influence from periphery to centre, and sub-divided into two sub-classes, according as (1) they excite the sensorial powers of the brain (*sensory nerves*), or (2) without producing sensation excite the motor powers of the *spinal system* by reflecting the influence which they conduct through the agency of the spinal marrow over to the central origin of a motor nerve (afferent portion of an excito-motory or physico-reflex nervous circle).

B. *Efferent or motor-fibres* always conduct in a centrifugal direction a motor impulse to the contractile tissues, and are also subdivided into two sub-classes—(1.) those in which the motor impulse *originates* in the brain, where it may be excited by an act of the will (*volitional impulse*), or by an emotion (*emotional impulse*),—(2.) those in which the nervous influence was first excited in an afferent nerve, and then reflected over to a motor nerve. Sometimes the influence to be thus reflected is conveyed to the ganglionic centre by a sensory nerve, so that sensation is a part of the process, (*consensual* or *sensori-reflex act*)—sometimes the impression is not at all felt, but is reflected by a purely physical process (*physico-reflex act*). The emotional and the sensori-reflex as well as the physico-reflex acts are alike independent of the will. The movements of respiration as executed under different circumstances may belong successively to each of these classes. The *nervous influence* exhibited by different classes of nerves is probably the same, the different results being due to the peculiar powers, not of the conducting fibres, but of the vesicular masses with which they are connected.

201. Exciting causes of the action of nerve fibres are, then, (1.) for afferent fibres, various modes of physical stimulation at their peripheral end, as pressure, mere contact, heat, sapid molecules, &c.—(2.) for efferent fibres, an immediately antecedent action of a ganglionic centre where the fibres originate, whether such action was excited directly by a psychical stimulus (volition, emotion, thought, &c.,) or by a physical stimulus derived from an afferent nerve and reflected through or by the ganglionic centre to a motor nerve (physico-reflex and sensori-reflex nervous circles.) Abnormal stimuli capable of arousing nervous action in either class of fibres and *at any part of their course*, are those which produce pretty violent irritation, whether mechanical or chemical, as punctures, pressure, cauterization, and especially an electric disturbance.—Proximate cause and laws to be noticed in connection with the topic which next succeeds.

GENERAL PHYSIOLOGY OF NERVE CENTRES.

202. *Assumed function :* to *originate* nervous force while nerve fibres are merely internunical agents—caution as to the sense in which the term '*originate*' is here employed.—Agency of nervous centres in *conducting*, *transferring*, *diffusing* and *reflecting* impressions. General laws and purposes of reflex actions—

203. Proximate cause of the actions to which the nervous system is subservient, or nature of the *vis nervosa*. Experimentum crucis which shows that the nervous force cannot be identical with any known form of the electric force. It is therefore held to be a *peculiar vital force*.

204. *Laws of nervous excitability.*—(1.) Conducted longitudinally only, being insulated in each tubule, and thus prevented from being diffused laterally—(2.) travels along the fibre with immeasurable velocity. (3.) Exhausted by continued exercise until after a sufficient interval of rest the power is restored. Explanation and proof of this law. (4.) Proportional to the energy of the local circulation of pure arterial blood throughout the nervous organs—Explanation—(5.) Moderate and habitual exercise followed by suitable intervals of rest favorable to the development of the organs and to the strengthening of the faculties. (6.) Increased by heat and depressed by cold. (7.) Increased by certain medicinal agents (*stimulants*), such as strychnine, small doses of alcohol and other narcotics, and electricity.—Depressed by certain other agents (*sedatives*) as chloroform, ether, and very large doses of narcotic stimulants. (8.) Mechanical friction revives nervous excitability when it has been blunted by extreme cold, or by severe pressure short of producing disorganization. (9.)—Nervous excitability is retained for a few hours in warm-blooded and several days in cold-blooded animals after somatic death, if it be not wasted. For if it be excited into manifestation by artificial stimulation, it is lost in a short time and is not regained—Explanation.

SPECIAL PHYSIOLOGY OF THE NERVOUS SYSTEM.

PHYSIOLOGY OF THE CEREBRO-SPINAL AXIS.

205. General characteristics of the vertebrated types of nervous system—continuity of vesicular matter in the cerebro-spinal axis, swelling out, however, at all particular points where the largest currents of afferent impressions enter and those of motorial power go out. The axis, divided into two great sections, namely, the spinal cord and the encephalon or brain, the latter being a series of ganglionic enlargements lodged in the cranial cavity, and including the following parts, each of which has distinct offices: (1.) *Medulla oblongata*, in direct continuation of the spinal cord, and therefore a conducting medium between it and the higher parts of the brain, but serving also by a part of its vesicular structure as a *special* and *independent nervous centre* for the physico-reflex movements concerned in respiration and deglutition. (2.) A series of ganglia at the base of the brain, connected with the nerves of sensation, and therefore termed sensory ganglia, among which should be ranked, it is probable, the *optic thalami*, as standing in

the same physiological relation with the nerves of common sensation that the other sensory ganglia do to the nerves of special sense.—(3.) *Corpora striata*, which are generally confounded with the cerebral hemispheres under the general term *cerebrum*. They seem to be centres of motor impulses that may be excited by a previous action of any of the sensory ganglia, all of which have a more or less direct communication with them, or they may be excited by volitional or emotional stimuli, conducted down to them by commissural fibres or internal nerves from the cerebral hemispheres.—(4.) *Cerebellum*—superposed upon the upper and posterior face of the medulla oblongata, and having extensive connections by commissural bands with the latter, and with all the other parts of the encephalon. Organ for *co-ordinating* muscular movements.—(5.) *Cerebral hemispheres*—superposed on the corpora striata and then gradually extending over the sensory ganglia, and ultimately, as in man, even over the cerebellum, so as to cover in all the other encephalic centres. Organs of the intellectual and moral faculties, and most probably of those peculiar powers of the lower tribes termed *instincts*, which with them are a substitute for the powers of reason—Connection between the separate encephalic centres, and between the same centres on the two sides of the body by *commissures*, such as *pons varolii*, *crusa cerebri*, *corpus callosum*, *peduncles of the cerebellum*, &c., &c.

PHYSIOLOGY OF THE SPINAL CORD.

206. Special anatomy of the medulla spinalis in man. Origin of spinal nerves by two sets of roots. Ganglia on the posterior roots—Cresentic masses of cineritious substance revealed by making cross sections of the cord.

Functions of the cord as determined (1) by comparative anatomy and experiments on lower vertebrata—(2) by results of disease—Thus shown to be a centre of physico-reflex actions, especially those which are subservient to egestion—also, a connecting and conducting medium between the brain and the roots of the spinal nerves.—Explanation of this latter function (1.) theory of Hall, Grainger, &c.; (2.) theory of Müller; (3.) theory of Todd;—application—Laws of reflex action—Degree of control of the mind over them in directing, modifying, hindering, &c.

PHYSIOLOGY OF THE MEDULLA OBLONGATA.

207. Structure of this part of the encephalon—(1.) Pyramidal bodies—(2.) Olivary bodies and olivary tracts—(3.) Restiform tracts—(4.) Posterior pyramidal tracts. Double character of the medulla oblongata, as a conducting medium between the medulla spinalis and the higher parts of the encephalon, and as an inde-

pendent centre of nervous power. With reference to the first function, notice the motor tract in front and the sensory tract behind, both decussating their fellows on the middle line. Restiform and olivary tracts are probably commissures of a more special kind. As an independent centre it contains (1) the *olivary nucleus*, the centre of the physico-reflex movements concerned in *deglutition*, (2) the *restiform ganglia* or centre of the physico-reflex movements concerned in respiration. Two of the sensory ganglia, namely, the auditory and gustative are, as will be presently seen, connected with this part of the encephalon.

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PHYSIOLOGY OF THE SENSORY GANGLIA.

208. *Comparative anatomy of the Encephalon.*—(1) FISHES. Four ganglionic masses, namely, from before backwards, olfactory ganglia, cerebral ganglia, optic ganglia and cerebellum. The cerebrum of most fishes probably homologous with the corpora striata of man, and not with the true cerebral hemispheres.

(2) REPTILES.—Cerebrum larger than any of the other ganglia, and consists of true cerebral hemispheres developed over the corpora striata with lateral ventricles between them. Cerebellum of variable dimensions.

(3) BIRDS.—Cerebrum very much larger than the other masses covers in the olfactory and in part the optic ganglia also. Cerebellum large and striated.

(4) MAMMALS.—Cerebrum still larger, covering entirely the optic as well as the olfactory ganglia, and in part also the cerebellum, which in man alone is completely covered by the cerebrum. In all but the Implacentalia the two cerebral hemispheres are connected by the great transverse commissure called the corpus callosum.

209.—*Enumeration of the sensory ganglia.*—(1) Olfactory—(2) optic, (*Tubercula Quadrigemina*). (3) Auditory, (*a mass of vesicular matter at the roots of the auditory nerve on the floor of the 4th ventricle.* (4) Gustative, *a small mass of cineritious substance at the root of the glossopharyngeal nerve into which a part of the sensory root of the 5th pair may also be traced.*) (5) Ganglion of common or tactile sensibility. The *optic thalami*, receiving the greater part if not the whole of the sensory tract coming up from the medulla oblongata, probably stand in the same physiological relation within the nerves of common sensibility which obtains between the other sensory ganglia and the nerves of the special senses. Carpenter associates the *Corpora striata* with the *optic thalami;* but it is more probable that they are independent centres of motorial power, having a connection with *all* the sensory ganglia through which they are commonly excited. The muscular actions of man being chiefly guided by tactile sensations, especially those seated in the muscles themselves, the corpora striata have a closer

connection with the optic thalami than with the ganglia of special sensation.

210. *Functions of the sensory ganglia.*—(1) Centres of SENSATION, but not of PERCEPTION, the former being wholly a *subjective* process, while by the latter the mind takes cognizance of *objective* realities. (2) But the sensory ganglia, (or rather, perhaps, the corpora striata connected with them) are also centres of motor influence which is *reflected involuntarily* in respondence to sensorial impressions (*consensual or sensori-reflex acts*). 3. And further the sensory ganglia exercise a sort of control over even the voluntary movements in so far as sensations are necessary to guide the will as to the extent and direction of its action. Examples stated and explained. Such operations are wholly different from the simple sensori-reflex phenomena and ought not to be confounded with them under the common term "consensual," as Carpenter seems to have done.

211. *Proof of the assigned functions.*—(1) Effects of removing the *cerebral hemispheres*, so as to show that the power of sensation may be retained. (2) Effects of removing any one of the sensory ganglia in *permanently* destroying the sensibility peculiar to its action and *temporarily* impairing the motorial powers. The impairment consists not in the loss of the control of the will over any muscle, but in an inability on the part of the animal to *regulate* its actions so as to maintain steadiness of gait. Examples cited and explained.

212. The animal INSTINCTS are assigned by CARPENTER to the sensory ganglia on the following grounds. (1) The instinctive acts are involuntary, and are performed in immediate respondence to sensations, that is, they are consensual. (2) The animals most remarkable for the variety and scope of their instincts, namely, the class of insects, have no cerebral hemispheres, their supra-œsophageal ganglia corresponding to the sensory ganglia of vertebrates. But the definition of Instinct implied in the first of these statements leaves out of view that which is in fact its very essence, namely the *peculiar mental impulse* that prompts animals to perform acts (often involving a complicated series of *voluntary* as well as of involuntary movements) subservient to their own well-being or that of their unborn progeny, but exhibited under such circumstances as to preclude the idea that they could possibly foresee such result. There is an admirable adaptation of means to secure useful ends, but the adaptation is contrived not so much *by* the animals as *for* them. And yet, though the *instinctive propensity* be thus implanted, the acts whereby the propensity is gratified may be and often are strictly voluntary in *the physiological sense* of the term. The peculiar instincts of animals are, therefore, to be contrasted, not with the volitional power, but with the reasoning faculties, by which man compares, judges, discriminates and adapts means to secure a forseen end. Tests of instinct as contradistinguished from reason. (1) The uniformity of the means by

which animals of the same species accomplish the same ends, even where they have been secluded from the moment of their birth from all intercourse with their fellows, and often too when a change of circumstances has rendered such means nugatory. (2) The perfection of the adaptation which often defies all attempts at successful rivalry on the part of reasoning man, this perfection being attained without previous training.

Thus the instincts of animals have more points of analogy with the intellectual and moral faculties than with the animal faculty of sensation, and hence it is presumable that they are located in the cerebral hemispheres rather than in the sensory ganglia. Nor is this conclusion invalidated by Carpenter's second proposition, for if it be shown that certain insects manifest some degree of intelligence, his anatomical doctrine of the non-existence of cerebral hemispheres in this class of animals falls to the ground. Examples cited from ALISON (Cyclopedia of anatomy and physiology) KIRBY and SPENCE, HUBER and others, of acts executed by bees, ants, &c., which have all the distinctive characteristics of reason.

FUNCTIONS OF THE CEREBELLUM.

213. (1) Comparative development of the organ in the different vertebrate classes. (2) Effects resulting from the removal of one or both lobes of the organ. (3) Effects of disease. Acute disease generally attended with symptoms of apoplexy, and reveals nothing as to the characters of the special functions of the cerebellum. Chronic disease of the cerebellum rare. Yet the few cases recorded confirm the conclusion derived from comparative anatomy and experiments, that the cerebellum has for its office to *coordinate the combined muscular actions necessary for executing locomotion, &c.*

214. Phrenological doctrine as to the office of the cerebellum, that it is the seat of the sexual instinct, refuted by the foregoing considerations. And besides, the alleged *facts* on which the doctrine is supported are disproved by later and more accurate observers. Thus it is *not* true that the castration of young males is followed by atrophy or arrest of development of the cerebellum, but the contrary effect is sometimes produced, as shown by LEURET and LASSAIGNE, who found that the average weight of the cerebellum in 21 geldings was 70, that of the same organ in 10 stallions being 61; the superiority of the former being probably due to their employment for draught and to the consequent habitual exercise of the organ in connection with that of the motorial powers. Nor is it true that there is such a frequent coincidence between diseased states of the cerebellum and functional disorders of the genital organs as to favour the phrenological doctrine, for out of 178 cases collected by BURDACH, only *ten*, or but little more than one in 18, presented such coincidence. Probable explanation of the coinci-

dence when it exists. Finally there is one case on record in which the sexual propensity was strongly manifested, and yet the cerebellum was entirely wanting. (Cruveilhièr's Pathological Anatomy, 15th livraison.)

FUNCTIONS OF THE CEREBRAL HEMISPHERES.

215. Structure of the cerebral hemispheres in man. A stratum of cineritious matter 3-16th of an inch thick, forming the superficies of the brain, and overlying a contained mass of white matter, which consists (1) of diverging fibres radiating from below upwards through the corpora striata and optic thalami towards the surface; and (2) of converging fibres returning as it were from every part of the surface and crossing the middle line to connect correspondent points of the two hemispheres. These last are called commissures. The former may be commissures between the corpora striata and optic thalami on one hand, and the cerebral hemispheres on the other.

216. Functions of the hemispheres ascertained (1) by the method of exclusion—(2) by evidence derived from comparative anatomy. Pretty regular gradation of development from class to class among all the vertebrata, and from the lower to the higher orders of the mammalian class. There is no such gradation as to the powers of sensation and motion, but there is a correspondently progressive development of intellectual and moral powers. Thus fishes have corpora striata and rarely a perceptible trace of cerebral hemispheres, and are almost or wholly destitute of intellectual faculties. A few families (as the squalidæ for example,) rise above the piscine standard of psychical endowment, and these are remarkable for a greater development of the hemispheres. Examples cited from the other vertebrate classes. The average weight of the human encephalon in proportion to that of the body is about as 1 to 40. The average of a large number of mammalian orders, is 1 to 186; of birds, 1 to 212; of reptiles, 1 to 1321, and of fishes, 1 to 5668. Apparent exceptions: in the goldfinch the proportional weight of the encephalon compared with that of the body is as 1 to 24, and the field-mouse as 1 to 31; but the great relative weight of the encephalon in these and some similar cases is *not* due to superior development of the cerebral hemispheres, but only to that of the sensory ganglia. The true cerebral hemispheres are larger in man in proportion to the whole encephalon, to the whole of the nervous system, and to the whole body, than in any other animal. (3.) By evidence derived from experiments—effects resulting from the removal of the hemispheres—effects produced by removing the cerebellum and sensory ganglia, the cerebral hemispheres being left entire. (4.) Evidence derived from pathological observations on man. Extensive lesion of the surface of both hemispheres always attended with mental aberration,

whereas extensive disease of other parts of the encephalon may exist without any impairment of intellect.

217. Conditions of the action of the cerebral hemispheres—encephalon receives nearly or about one-fifth of all the blood in the system—arrangement of the arteries at the base of the brain for insuring an active arterial circulation through the organ and at the same time preventing any sudden and violent impulse of the blood upon the cerebral substance when the heart's action is suddenly increased. A certain amount of pressure also necessary, which is equalized by means of the easy displacement of the cerebro-spinal sub-arachnoid liquid.

218. CONNECTION BETWEEN THE MIND AND THE CEREBRAL ORGANIZATION. Statement of the opposed doctrines of MATERIALISM and SPIRITUALISM. Physiology lends no countenance to the former, while the latter seems to be a legitimate induction from the facts of consciousness. It is held by the materialist (1) that inasmuch as the mental faculties are developed *pari passu* with the development of the brain, partake of its disorders and cease to be manifested when it ceases to act, hence mind is nothing but a set of faculties attached to the brain in the same way as contractility is a faculty attached to muscle, or electricity a set of properties attached to sealing wax and other bodies. But all these facts are equally well explained on the hypothesis of a separate mental entity operating through the brain as its instrument. (2.) That there is no evidence of the existence of mind in a state separate from organization; to which it has been well replied, "that the whole universe displays the most striking proofs of the existence and operation of intellect or mind, in a state separate from organization, and under conditions which preclude all reference to organization." (3.) That the weight of proof rests with those who assert the independent existence of a mental entity; to which it may be replied, that since the belief in mind as separate from matter is one of those "first truths" which constitute the "primary elements of human reason," it devolves upon those who deny the validity of such intuitions to sustain their position, which thus appears to be at variance with the common and instinctive belief of mankind. But further, as regards material phenomena we observe that they have all "a certain relation to each other, so that they may be referred to certain general principles, but no analogy of this kind can be detected with respect to mind" in its connexion with the brain.—The foregoing heads of arguments expanded and illustrated.

PHYSIOLOGY OF THE SENSES.

219. Definition of SENSATION as that state of consciousness which is excited by the appropriate action of a sensory ganglion, which is usually, but not invariably dependent on a prior impression upon the peripheral expansion of a sensory nerve. Exclu-

sively *subjective* operation of the mind in simple sensation, as, probably, in the case of the earlier experiences of infancy.

220. Definition of PERCEPTION, as the faculty by which the mind refers sensations to an *outward cause* and forms certain notions with regard to the qualities of the outward agent. Examples.

221. Physiological mechanism of sensation. (1) Impression on the peripheral expansion of a sensory nerve effected in different ways—(2) conducting action of the nerve fibres—(3) action of a sensory ganglion consequent on the reception of the influence thus conducted. Possibility of stimulating the ganglion abnormally so as to supersede the two first processes without altering the character of the resulting sensations, as in dreaming, delirium, congestion of the brain, &c.

222. Classification of sensations. I. *External sensations*, of which there are five kinds, namely, touch, taste, smell, hearing, and sight. II. *Internal sensations*, resulting from organic changes in the organs independent of direct impressions from without, as flashes of light seen in cases of inflammation of the retina though the eye be excluded from all source of illumination. Hunger, thirst, the feeling of lassitude, &c., are instances of internal sensations. All of the internal sensations which are not clearly referrible to one of the *special* senses are believed to depend on the action of the same nervous apparatus which when impressed by an external agent gives rise to simple tactile sensations, and hence the sense of touch is called the *common or general sense.*

223. *General physiological laws of perception.* I. Every sensation of whatever kind immediately attended by certain *intuitive general perceptions*, as (1) the reference of the sensation to some *outward* cause, constituting the foundation of our belief in an external world, and (2) the location of the impressing agent at the extremity of the sensory nerve, even when in reality the impression has been abnormally applied elsewhere. It follows as a corollary from this law that where the elementary fibres of certain sensory nerves (those of touch and sight) may be separately impressed the perception of superficial figure will be likewise intuitive. II. Each special sensation is attended by *certain intuitive special* perceptions peculiar to its own class. Thus perception of colour is peculiar to the eye. Such perceptions are immediately dependent on the associate sensations, and are independent of the mode in which the nerves are impressed, or of the nature of the impressing agent. Hence the transference of *special sensibility* from one set of nerves to another is impossible. Electricity excites the action of all sensory nerves, but the resulting sensations are very different in the different cases, in each case being the sensations peculiar to the nerve impressed. III. Therefore the immediate object of perception is not the impressing agent but the change produced by it in the organs of sense, but inasmuch as the organs of sense participate in the properties of matter, having

extension, being susceptible of pressure, motion, alteration of temperature, &c., we reason from these changes to the qualities of the agents which produce them and thus have certain *acquired perceptions*. IV. While the passive susceptibility of *sensation* is blunted by habit, the active power of discrimination, or the delicacy of the perceptive faculty is increased by frequent exercise. V. The intensity of the sensation and consequently the distinctness of the perception depends more on the relative than on the absolute change in the sensorium—illustrations:

SENSE OF TOUCH.

224. Class of nerves concerned. Proof that tactile sensibility is merely one mode of general or common sensibility. Structure of the skin as an instrument of touch.

225. Varieties of common sensation, external and internal; as tact or pricking, pressure, temperature, itching, hunger, thirst, venereal feeling, cœnaesthesis, muscular sense, &c., &c.

Special intuitive perceptions connected with such sensations, as the idea of *resistance*, *weight*, *temperature*, as a quality of external bodies; *dryness* or *moisture*, &c., &c. Tactile perception of superficial figure and dimensions, in what degree intuitive and to what extent acquired. Assistance derived from the muscular sense in giving greater precision to our intuitive tactile perceptions.

SENSE OF TASTE.

226. Structure of the organ. Physical state of the surface essential to its action. Nerves concerned. The cause of sapidity in bodies only cognizable by its power of impressing the organ of taste. Its varieties as indicated by the terms, *sour*, *sweet*, *bitter*, *acrid*, &c., &c., as well as the infinite nameless varieties.

The perception of the differences between these varieties is intuitive, but the association of each with a certain body or class of bodies is, of course, acquired, and becomes important as a means of distinguishing such bodies. Sympathies of the organ of taste.

SENSE OF SMELL.

227. Proof of the olfactory sensibility of the first pair of cranial nerves. Physical condition of the pituitary membrane essential to the exercise of this function. Use of the antrum and other sinuses. Physical cause of odors. Varieties of odors. Intuitive perception of these variations. Acquired perception

of other qualities of bodies by means of their association with peculiar varieties of odors. Affinity between the sense of taste and smell.

SENSE OF HEARING.

228. Anatomy of the apparatus of hearing in different animals. (1) A simple sacculus on the inner walls of which the auditory nerve is distributed, imbedded in the flesh without any fenestral opening into the chamber; as in GASTEROPODS and CEPHALOPODS. (2) The same kind of sacculus lodged in a chamber which has a fenestral opening closed with a vibratile membrane; as in the basal segment of the lesser antennæ of certain CRUSTACEANS. (3) FISHES have, in addition to the sacculus, a vestibule and semicircular canals of which except in the lowest order, there are always three arranged as in man. The whole apparatus lodged in a depression of the inner surface of the cranium, which communicates with the cranial cavity, except in the higher cartilaginous fishes. (4) REPTILES have rudimental cochlea, fenestra ovalis, stapes, and all but the lower amphibians and ophidians have a tympanic cavity. (5) BIRDS have a more highly developed cochlea divided into two scalæ although still straight, fenestra rotunda, tympanum, columella, &c. (6) MAMMALIA have a spiral cochlea and an external ear or auricle in addition to the parts existing in the lower classes. Proof of the special character of the portio mollis nerve.

229. External cause of sounds. Modes of propagating sonorous vibrations from the sounding body to the ear. (1) *Conduction* by *progressive* vibrations excited by the *stationary* waves in which the sound originates. Loss of energy in the transference of progressive vibrations from one medium to another of different physical nature. (2) *Reciprocation*, or the excitement of *secondary stationary vibrations* in certain bodies which are particularly susceptible of such action, particularly organic membranes and strings made elastic by tension, when they are placed *near to*, but not in contact with sonorous agents with which they can vibrate in unison.

Conditions necessary for the production of these secondary reciprocating vibrations, which giving an additional impulse to the air, increase the intensity of the sound as produced by the primary sounding body. Water *conducts* the vibrations thus produced in reciprocating solids, and thus we obtain a means whereby sound may be imparted from air to water.

(3) *Resonance*, consists in increasing the extent of surface of a soniferous medium, similar in kind to the primary sounding body. It is thus, a kind of reciprocation, but differs from the foregoing in this, that the sounding board *must* be in contact with the sonorous body, and need not have the peculiar susceptibility of organic membranes. Resonance much favoured by the *insulation* of the resonant medium.

230. Mechanism of the ear in audition, and uses of the several parts of the complicated apparatus. The essential part of an organ of hearing being a nerve of special endowments, so disposed as to receive sonorous impressions to the greatest advantage, it will be more natural and easy to consider the uses of those parts which exist in all the varieties of such apparatus, and those of the superadded structures in the order in which they successively appear. (1) Uses of the *endolymph;* probably, to maintain on the surface of the nerve the same physical condition which necessarily exists in its interior parts. (2) The *sacculi* and *the ear dust.* "Sonorous vibrations are not only imparted from water to solid bodies bounded by definite surfaces which are in contact with the water, but are also returned with increased intensity by these bodies to the water, so that the sound is heard loudly in the vicinity of those bodies in situations where, if it had its origin in the conducting power of the water alone, it would be faint."—(MULLER). Experimental evidence of the effect produced by solid bodies floating in the liquid of a sac whose walls are thrown into vibration. (3) *Perilymph* and *fenestra ovalis with its membrane.* The latter a reciprocating medium by means of which vibrations of the air are transferred to water which is the final impressing agent. (4) *Semicircular canals.* Conjectural view of their office as connected with the perception of the direction of sounds. (5) *Cochlea*—supposed to be an arrangement for the advantageous reception of the vibrations conducted by the bones of the head. Spiral form, not essential and exists only among mammals, being, as is probable, an arrangement for convenience of package. (6) *Fenestra rotunda and its membrane.* This membrane and that of the fenestra ovalis being unequally distant from the auditory nerves the phenomena of "interference" of the sonorous waves ensue, whereby there is occasionally produced a more intense impression on the nerve. (7) *Tympanum, with its ossicles.* The vibrations of the air may be communicated to the perilymph by the simple interposition of the membrane of the fenestra touching the water on one side and the air on the other, but in a far more perfect manner, as proved by experiments, by connecting this membrane by means of a rod with a second membrane having air on both sides, particularly if the rod be insulated in a space bounded by definite walls like the tympanum. Explanation and application to the case of the natural tympanum. (8) *Mechanism and uses of the membrana tympani*, as adjusting the ear to sounds of different degrees of intensity and pitch. Experimental method of increasing the tension of this membrane, by a voluntary effort and its effect in blunting the sensibility of the ear for all except very acute tones. (9) *Eustachian tube* serves to carry off secretions, and also to maintain an equilibrium of pressure on the two sides of the membrana tympani. (10) Mastoid cells are resonant cavities. (11) *Auditory canal* a resonant medium, both by the air in its cavity and by its walls, which also conduct the vibrations of (12) *Auricle*, a recipro-

cating instrument with various inflexions of its surface of which the probable use is to receive the progressive undulations at right angles from whatsoever direction they come. The concha with the auditory canal forms a hearing trumpet.

231. Perceptions connected with the exercise of this sense. (1) Of the variations of intensity of sound. (2) Of musical pitch, which is dependent on the number of vibrations in a second, or rather on the interval between two successive impulses, as exemplified by experiments with the "*siren*." Physical condition of harmony and melody. The "musical ear" whether dependent on the conformation of the ear or on the organization of the brain. (3) *Tone* or *timbre*, varies with the physical nature of the sounding body, &c.

Physiology of Sight.

232. Possible forms of organs of vision. The sensation and perception of luminousness may exist without any optical apparatus, and require only the presence of a nerve with special endowments. In general, however, we find associated with such a nerve one of three forms of optical apparatus for supporting the nervous expansion and for concentrating or otherwise modifying the luminous rays. (1) *Ocelli* or *Eye-dots*, found in many of the Annelida and in the larva state of many insects, &c. (2) *Compound eyes* of insects and crustaceans, of which there are several varieties. (3) *Simple eyes* of cephalopod molluscans and all the vertebrate classes.

233. Optical principles involved in the exercise of the eye as an organ of vision. (1) Physical cause of the visibility of bodies. Self-luminous bodies and bodies luminous by reflection. (2) Radiation of light in all directions from a luminous centre and its passage in straight lines so long as it is in the same medium. (3) Laws of reflection of light from the surface of bodies—opake and transparent bodies. (4) Laws of refraction. *Index of refraction* or the ratio of the sine of the angle of incidence to that of the angle of refraction constant for all angles, the media being the same. (5) Effect of the convexity of a refracting medium in causing diverging incident rays to converge on passing out. (6) Relation between the distance of a luminous point in front of the lens and focal distance. (7) Aberration of sphericity—how obviated. (8) Aberration of refrangibility or dispersion of colored rays. Achromatism, how obtained. (9) Mechanism of the camera obscura.

234. Mechanism of the human eye. A globular camera obscura. Advantage resulting from the globular form. Cornea, aqueous humour, crystalline lens and vitreous humour appear to form an aplanatic and achromatic combination. Fluidity of the aqueous humour necessary for admitting the movements of the

iris, a diaphragm or stop for cutting of the peripheral rays when the light is too intense, or when looking at very near objects when spherical aberration would be likely to ensue. Muscularity of the the iris and its mechanism. Adjustment of the eye to vision at different distances, probably by the agency of ciliary processes and the ciliary muscle.

235. Explanation of the phenomena of vision. (1) Simple perceptions of light dependent on any adequate excitement of the organ of vision though the sensation be entirely internal and be produced in perfect darkness. This is probably the sole function of certain forms of ocelli. (2) Simple perception of colour. Physical explanation of the colour of transparent and opake bodies. Physiological explanation of the perception of colour, according to the undulatory theory. Complementary colours. Colored spectra whether positive or complementary, and their physiological explanation. (3) Perception of the position of a luminous point; size of aliquot portions of the retina possessing the power of independent sensation; law of visible direction. (4) Perception of superficial extension shewn to be a necessary consequence of the foregoing law and therefore intuitive. Error of Locke and other metaphysicians in denying the identity of tactile and visual perceptions of plane figures, whereas only the *sensations* and not the consequent *notions* differ. See case of young man restored to sight by an operation for cataract, performed by Dr. Franz and recorded in the London Philosophical Transaction for the year 1841. (5) Perception of solidity. With the use of one eye only this perception must be *acquired;* but with both eyes the notion is intuitive. Mechanism of the stereoscope invented by Wheatstone; physiological interpretation. (6) Single vision when both eyes are used. Theory of identical or correspondent points on the two retinæ with the assumed physiological explanation. Objections to the theory. (7) Erect vision, the image on the retinæ being inverted, does not need explanation, since the images of all surrounding objects that might be used for comparison, are likewise inverted. (8) Estimate of the size of visible objects. Actual and ideal size of the field of vision; "visual angle" or measure of the size of the image on the retina dependent on the *size* and *distance* of the visible object. Hence when the latter element is not known we are subject to deception in our estimate of the former. (9) Appreciation of distance determined in part by visual angle when the size of an object is previously known. Angle of convergence of the axis of the two eyes. Interposition of known objects. Variations of the intensity of light and shade. (10) Visual perception of the motion of objects. (11) Duration of visual sensations giving rise to luminous spectra. (12) Vanishing of images which fall at the entrance of the optic nerve. (13) Visual representation of the retina itself by the experiment of Purkinje.

SPECIAL PHYSIOLOGY OF THE CEREBRO-SPINAL, AND OF THE SYMPATHETIC NERVES.

236. Method of determining the special functions of a nerve. Effects resulting from the experimental irritation of a nerve according as it may prove to be a nerve of motion, or of sensation, or an afferent nerve belonging to the physico-reflex system. Effects resulting from the section of a nerve belonging to either of these classes.

237. Functions of the spinal nerves at their anterior and posterior roots. Subsequent mingling of the fibres in trunks and branches of mixed functions. Formation and function of the phrenic and other spinal nerves.

238. Physiological classification of the cranial nerves. Reference to the text-book for a detailed account of the functions of each.

239. Reference to text-book for account of the actions of the SYMPATHETIC NERVE, the office of which is, probably, to establish a harmony of action between the organic operations of distant parts. Sometimes this is accomplished by means of physico-reflex movements, of which the nervous centre is one of the sympathetic ganglia, as seems to be the case with the peristaltic movements of the intestinal canal. But frequently the sympathy is exhibited by an *exaggerated*, *diminished*, or *perverted secretion*, or *act of nutrition*, which cannot be explained by supposing that the reflected nervous influence operates on the muscular function of the small arteries. We must, therefore, admit that some efferent nerves convey an influence which operates on the nutritive functions directly. It is true that this influence is not *essential* to the performance of the nutritive acts, as has been erroneously represented by PAGET, but it is capable of accelerating, retarding or modifying the character of those acts. Examples cited.

240. Summary recapitulation of the physiology, general and special, of the nervous system.—The final causes of the nervous functions may be summed up as follows:—(1) As subservient to the excitement of those movements of animals which depend upon stimuli *not felt* but reflected from an impressible surface, through a circle composed of an efferent nerve, a ganglionic centre and an efferent nerve, to distant muscles, (*physico-reflex movements.*) (2) As subservient to the manifestations of the conscious mind and to bringing it into relation with the external world, either by receiving sensorial impressions which give rise to certain fundamental ideas of perception or by reacting on matter through the instrumentality of the motorial apparatus stimulated by sensations, (*sensori-reflex* or *consensual*), emotions (*emotional*), thoughts (*ideo-motor*), or the will (*volitional movements*). (3) To establish a harmony of action between different parts of the system. See above, § 239.

PHYSIOLOGY OF THE SENSIBLE MOTIONS OF ANIMALS.

241. Locomotion occasionally though rarely exhibited by vegetable structures, and only strictly peculiar to animals as executed in respondence to stimuli *acting through a nervous system.* Contractile cells of certain vegetable structures—phenomena of ciliary motion (see § 27).—In both these cases the action seems to be inherently *rythmical*, that is, a single excitement is adequate to give rise to a prolonged series of contractions alternating with relaxations.

242. *General Physiology of muscular action.* Statement of the functions—(1.) Sudden and rythmical contractions causing the displacement of moveable parts to which the muscles are attached, or the propulsion of matters contained in hollow viscera whose walls are formed by the contractile muscular fibres. (2.) A more slow and permanent contraction which *gives tone* to the muscle itself and often subserves the office of *regulating the calibre* of tubes around whose walls the contractile fibres are circularly disposed.

Explanation. I. Rythmical contractions excited normally by nervous influence, but may be excited by direct mechanical or chemical stimulation of the fibres themselves. The *proximate cause* of such contractions is a peculiar inherent *vital* property which has been called *irritability*, but is more appropriately termed *contractility*, and this endowment of the muscular fibre is an "*ultimate fact.*" Proof of this statement. Laws of muscular contractility—(1.) Disintegration of tissue coincident with each contraction.—(2.) Necessity of active arterial circulation—(3.) necessity for intervals of rest after prolonged action—(4.) force of contraction proportional to energy of stimulation—(5.) development of heat—(6.) production of a peculiar murmur—(7.) velocity of contraction under certain circumstances. II. *Tonic contractions* either dependent on a distinct vital property, *tonicity*, or else on the ordinary contractility kept in a state of sustained operation by the influence of a permanent stimulus. Phenomena of cadaveric rigidity.

PHYSIOLOGY OF THE VOICE.

243. The human voice consists of the sounds produced by the air in its passage through the *larynx* with a certain degree of *expiratory* force, and in a certain position of the inferior laryngeal ligaments. The organs concerned include not only the whole respiratory apparatus with that portion of the nervous system which is subservient to the excitement of the respiratory muscles, but certain superadded parts, such as the pharynx, mouth, tongue, lips and nasal cavities, which modify the laryngeal sounds so as to

constitute articulate language. The special organs are the inferior laryngeal ligaments, therefore called *vocal cords*, which are thrown into vibration by the impulse of the air in expiration, after being first placed in a vocalizing position by the thyro-arytenoid muscles.

244. Preliminary notice of some of the phenomena of acoustics. Physical cause of sounds and the circumstances which determine the *pitch*, the *intensity*, and the *timbre* of sounds.

245. *Laws of vibrating strings.* The fundamental note being that which is due to the vibrations of the string by its entire length, the number of vibrations for shorter lengths is *inversely* proportional to the length, thus:

	Fundamental.		*Third.*		*Fifth.*			*Octave.*
No. of vibrations, -	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
Length of string, -	1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{8}{15}$	$\frac{1}{2}$
Names of notes, -	C.	D.	E.	F.	G.	A.	B.	C^1.

The length being constant, the number of vibrations is proportional to the *square root* of the tension.

246. *Wind instruments.* In these the contained air is the seat of sonorous undulations passing backwards and forwards from one end of the column of air to the other, the rapidity depending on the length of the wave or of the space which it traverses. Hence the number of vibrations is inversely proportional to the length of the tubes. A tube open at its extremity yields a fundamental note an octave higher than a closed one, a nodal point being formed in the middle of the column of air. In either kind higher notes are produced by increasing the force of the blast, but the nearest note to the fundamental one is, under such circumstances, its octave.

247. Instruments in which the properties both of solid and of fluid elastic bodies come into play. Reed or tongued instruments. Laws of the vibrations of membranous tongues with superadded tubes. The pitch of such a tongue may be raised almost an octave in *successive semitones* by altering the force and manner of the blast.

248. Structure of the larynx. Classification of the laryngeal muscles.

(1) MUSCLES WHICH REGULATE THE TENSION OF THE VOCAL CORDS AND THUS GOVERN THE PITCH OF THE NOTES.

Crico-Thyroidei, *Sterno-Thyroidei* — Depress the front of the Thyroid cartilage on the cricoid, and *stretch* the vocal cords. They are assisted by the Arytenoideus Transversus, and the Crico-arytenoidei postici.

Thyro-Arytenoidei, *Thyro-Hyoidei* — Elevate the front of the Thyroid cartilage and draw it towards the Arytenoid and thus *relax* the vocal ligaments.

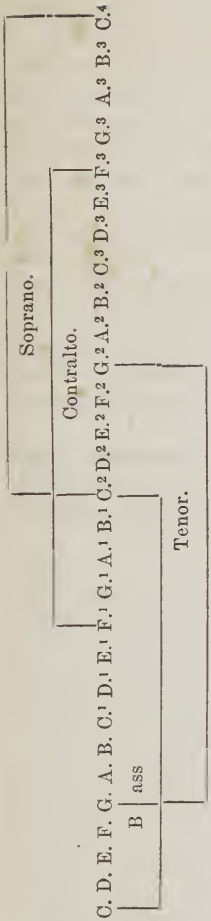
(2) MUSCLES WHICH GOVERN THE APERTURE OF THE GLOTTIS.

Crico-arytenoidei postici . . . Open the glottis.

Crico-arytenoidei laterales
Arytenoidcus transversus } Press together the inner edges of the Arytenoid cartilages and close the glottis.

249. Position of the vocal cords in simple respiration; vocalizing position; mean length of the cords of the adult male, 0.728 of inch in repose and 0.912 in greatest tension. Of the adult female 0.498 and 0.617. Shape of the aperture in different positions of the ligaments and of the arytenoid cartilages.

250. *Modulation of the voice.* Müller's experiments on the artificial production of the voice with the larynx separated from the dead body. Upper ligaments and epiglottis shown to be merely or chiefly reciprocating and resonant media for increasing the *loudness* of sound, but not for altering their pitch. Pitch of the notes regulated by the length and tension of the vocal cords. Compass about two octaves. Two distinct series of notes, namely, the ordinary and the falsetto register. The highest notes always belong to the falsetto, and the lowest always to the ordinary register, but if a moderate tension of the ligaments be maintained, it depends on the manner of blowing whether the ordinary or falsetto note be produced, (the latter being most easily produced by blowing very gently,) and the two different notes thus pro luced may be very distant from each other in the musical scale, even as much as an octave. Müller's explanation of the falsetto notes. Mode of successively raising the pitch of the ordinary voice without running into the falsetto register. Influence of narrowing the diameter of the larynx immediately below the vocal cords, which is effected by the action of the Thyro-arytenoid muscles. Other uses of these muscles. Condition of the vocal cords in the production of different notes from the deepest bass to the highest tenor.



251. *Theory of the voice.* The human voice held to be a reed instrument with a double-membranous tongue. When simple vibrating strings are very strongly touched *deeper* notes are produced, whereas the note given out by a moist membranous tongue is *raised* by a stronger blast the extent of many semitones.

252. Three different kinds of sequence in the notes of the human voice.

(1) *Monotonous*, as in speaking, only occasional syllables receiving a slightly higher intonation for the sake of accent.

(2) Successive transitions from high to low notes and *vice versâ*, as in the involuntary cries of pain, &c.

(3) Musical sequence. Compass of the voice in different individuals. Varieties of male voice, technically called bass, barytone and tenor, and of the female, contralto, mezzo-soprano and soprano. The ordinary compass of each may be seen on the scale placed in the margin.

These different kinds of voice differ also in timbre so as to be distinguished when sounding the same note. Difficulty in hitting upon the right note when passing suddenly in singing from the natural to the falsetto register, or from a low to a loud tone.

253. Differences of the voice as to timbre, dependent on the form of the air-passages and on their resonance. A nasal tone may be given in two ways. (1) When the external openings to the nares are closed, the voice may become nasal by the approximation of the arches of the fauces, and by the larynx ascending higher than when the voice has its natural character. Obstruction of the nostrils by mucus has the same effect as closing the anterior nares, but neither the one nor the other can alone give the nasal tone to the voice. (2) The nasal twang may also be given when the nostrils are open, the mouth being either open or closed. In this case likewise the larynx ascends considerably; the arches of the fauces contract; and the dorsum of the tongue is approximated to the palate or brought into contact with it; and the air merely passes between the narrowed arches of the fauces and receives the resonance

of the nasal cavities without that of the cavity of the mouth.—(MULLER.) Character of the voice at different epochs of life.

254. *Strength of the voice* as dependent partly on the capability of vibration of the vocal chords and partly on the fitness of the membranes and cartilages of the larynx and of the adjacent organs for resonance. Increased intensity of vocal sounds produced by an increase in the force of the blast; but as this same change alters the pitch of the notes, there must be some means of compensating this tendency to emit a higher note, which probably consists in relaxing the vocal chords in a suitable proportion.

255. *Perfectness of notes.* Cause of dissonance after long singing; cause of habitual dissonance. Explanation of the power to reproduce given notes in singing by ear or by note. Musical sounds formed in the mouth as in *whistling* where the air is the source of the sounds, by friction against the borders of the opening.

256. *Articulate sounds or speech.* Division of articulate sounds into vowels and consonants and mode of producing each. *Mute* vowel and consonant sounds. *Explosive* and *continuous* sounds. Ventriloquism.

GENERAL CONSIDERATIONS HAVING REFERENCE TO THE CONDITIONS OF VITAL ACTIONS.

I.—*On the connection between Life and Organization or nature of the Vital Principle.*

257. Some of the actions of man the result of mechanical arrangements of parts endowed with purely physical properties. Examples cited and explained. So also other actions result from the operation of purely chemical forces. But a large number of the actions of the human organs cannot be referred to either of these classes, and are found to indicate the existence of properties or forces *peculiar* to *living* organized structures, and accordingly these forces are denominated *vital*. The investigation of the laws of these forces must be pursued by the same inductive process which is employed in other departments of positive science.

258. Is there an *essential* distinction between vital and physical forces? Two opposing views in regard to this question which is rather speculative than practical. (1) Doctrine of the *vitalists* who hold that the proximate cause of all the truly vital acts is a *special entity* which they denominate the VITAL PRINCIPLE and which they consider to be as independent in its essence of the tissues which it animates as the SOUL is of the brain through which it acts. According to this view a tissue, an organ, or the whole body may die, by reason of the vital principle deserting its material tenement, though the latter may be uninjured. (2) The advocates of the opposing doctrine hold that the vital properties depend on the structure of organized tissues, just as physical properties depend on the special forms of matter by which they are manifested, the main difference being that the structure of organized tissues is in many of its features so refined and delicate that it can never be successfully imitated and therefore no vital act, not even the simplest, can ever be artificially exhibited. This would seem to be the most philosophical view of the subject, on the simple ground of the entire absence of any satisfactory foundation for the opposing doctrine, which also seems to be disproved by the fact that each tissue and even minute fragments of tissue possess independent vitality, which would require us in adopting such a doctrine to admit the existence of several hundred vital principles. Thus BROWN—SEQUARD has shewn that entirely dead muscles of one animal may have their power of vital contractility restored to them by connecting their blood-vessels with those of a living animal of the same species, in such a manner as to cause the circulation of living blood through the previously dead muscle.

259. Examination of the arguments adduced by the vitalists. (1) Unity of the vital acts all of which point to a common purpose. But this only indicates the *final cause* and not the *instru-*

mental method; and the same argument might be used with reference to the operations of any machine exhibiting design, and the skilful adaptation of means to a specific end. It is clear in all such cases that the cause of the unity, lies in the designing mind of the contriver and architect, who arranges a mechanism with reference to the production of such an effect; and in the case of living machines, it would be not less derogatory to the Great Author of Nature, to ascribe the wonderful unity of plan and purpose to an imaginary *vital principle*, than to refer it to a property of brute matter. It is just as easy to suppose, that the Almighty uses brute matter as his *immediate* instrument in the production of vital acts, as that certain intermediate agencies or vital entities are indispensable. Indeed, the latter hypothesis is much the grosser of the two, and seems to have its origin in an unconscious ascription to the Almighty of some of the imperfections which belong to man, namely, the impossibility of acting upon matter except through secondary instrumentalities. Again, if this argument of the vitalists were valid, then by a parity of reasoning the universe should have its vital principle, since it may be said to be organized in the sense of being composed of diverse but mutually adapted parts, the operations of each of which tend to the stability of the whole, as abundantly shown by writers on natural theology. Accordingly those vitalists who have logically followed out their principles have naturally ended in Pantheism.

260. (2) The limited duration of organized structures, each species of plants and animals having an appointed term of life, is adduced as an argument in favor of vitalism. But it is as easy to believe that the structure of a living body is such as to wear out after a certain amount of use, as that an immaterial principle enters the germ at conception, remains in connection with the growing plant or animal and after a certain time leaves it.

261. (3) The bodies of living animals resist (the vitalists assert) the operation of the ordinary forces of matter, as for example, the tendency to putrefaction, which is restrained by the controlling influence of life, and which ensues immediately after the withdrawal of life. But it may be shown that the ordinary forces of matter are not *resisted* however their effects may be *counteracted* by the vital acts. For example a decay analogous to putrefaction is constantly going on, but the products are separated from the blood by the depuratory glands, and finally discharged from the body in the form of the different excretions.

262. (4) It is alleged that sometimes life is destroyed without injury of the material fabric, as when death suddenly ensues from mental emotion, from a stroke of lightning, &c. But this is an unproved and highly improbable assumption. In very many such cases adequate lesions are found in the heart and brain, and when we reflect upon the complicated composition of the blood and of the semi-solid substance of the nervous system, we can readily conceive

that there may be many kinds of disturbance incompatible with health, and even with life, and yet not appreciable to the eye.

263. (5) Impossibility of artificially exhibiting vital phenomena. This is admitted, for we cannot artificially construct the material frame. The simplest and at the same time the most essential structural element of organization is the primordial *cyto-blast* or *cell germ* of so refined a structure and composition as to be incapable of exact appreciation. Of course this microscopic body cannot be imitated. The argument can have no value until a perfect organism *has* been constructed and then be found to need the Promethean heat of a vital principle.

264. The charge of materialism cannot be fairly brought against the doctrine here contended for, since in rejecting the hypothesis of an independent vital principle reference is had to those vital phenomena which man possesses in common with the lower animals, and which are irrespective of the sentient and conscious mind. Whereever sensation or any other *mental* act is concerned, it is admitted that an immaterial and independent agent is operating through a material organ. The question here considered is whether the organic acts depend on a similar entity to be called the Vital Principle. The arguments in favor of the immateriality of the sentient and thinking principle do not in the least degree apply to the case in question, but on the contrary the *materiality* of the phenomena of organic life may be legitimately inferred from their very contrast with the phenomena of mind.

565. Notice of a *metaphysical* sense in which vital forces, as mere objects of cognition, may be regarded as distinct from the organized tissues by which they are exhibited. But this is equally true of all forces, physical as well as vital, and cannot give any countenance to the doctrine of vitalism, which affirms the existence of an independent vital entity, but denies the existence of any correspondent inanimate material principle, on the ground of an essential difference between the two classes of acts.

266. In the absence, then, of any proof to the contrary, we conclude that the vital phenomena are the results of vital forces operating through organized matter, *precisely* as other natural phenomena are the results of physical forces acting through inanimate matter, and that we have no better reason to ascribe an independent existence to the former than to the latter, but that on the contrary, the remarkable correlation between these two classes of forces constrains us to admit their *essential* similarity. (See Carpenter's Elements of Physiology, § 52 to § 73.)

II.—ON THE EXTERNAL CONDITIONS OF VITAL ACTIVITY.

267. Threefold condition of vital actions—(1) an organism—(2) alimentary materials requisite for the construction and maintenance of the organism, and (3) the *dynamical* conditions, or the

forces or powers on which its operations are dependent. Now the vital forces seem themselves to result from the operations of certain physical forces, especially *light* and *heat*, on duly organized structures. The higher the organization the greater the dependence on these forces. Their influence rather *relative* than *absolute*. Apparent distinction between living bodies and inanimate masses of matters in this respect. The proper interpretation of this fact, as connected with the change which the organism itself undergoes by any considerable alteration of the doses of stimuli to which it may be exposed.

(*a*) OF LIGHT AS A CONDITION OF VITAL ACTIVITY.

268. Notice firstly the influence of light as a condition of chemical action, sometimes determining the union of bodies, as of hydrogen and chlorine, and sometimes effecting chemical decomposition. Secondly, its influence on the functional activity of plants, as (1) on the development of the vegetable structures, acting in two ways, namely, by directly exciting the chemical acts concerned in the fixation of carbon and by regulating the action of the stomata, so as indirectly to regulate the absorption of fresh material. Hence exclusion of light arresting these processes, causes plants to become pale, succulent and dropsical; a condition which often increases their value as aliments but renders them unhealthy as natural beings. Germination retarded by light, a plant during germination resembling an animal in its relation to heat and consequently to carbon, which it then *consumes*. (2.) Influence of light on the motion of plants, as the direction of the growing stem, the expanding of flowers and their turning towards the source of light.

269. Influence of light on the functions of animals—(1) on the development of the body; Humboldt's testimony with regard to the perfect development of the bodies of savages who go habitually uncovered. Deprivation of this influence seems to be one of the causes of scrofula, rickets and other diseases leading to bodily deformity. Tadpoles prevented from undergoing metamorphosis by confinement in the dark. (2) On the functions of the skin. Ruddy complexion of health belonging to persons living in the country contrasted with the etiolation of inhabitants of the city. An excess of the stimulus produces freckles and other diseases of the skin. (3) On the functions of the nervous centres. The influence in moderation is wholesome; in excess produces excitement, pain, or even delirium and death by sun-stroke; lunar influence on maniacs. (4) On the general health, as indicated by liability to disease and by the rate of mortality under the operation of disease. (See *Carpenter, loc. cit.* § 95.)

On the whole subject of the influence of light as a vital stimulus. See Ibid. § 79 to § 97.

(*b*) On heat, as a condition of vital activity.

270. Notice of the influence of heat as an exciting cause of mechanical and chemical changes. Its influence on vegetation on a large scale, exhibited in the changes produced by summer and winter and confirmed by the experiment of artificially inverting the seasons. Geographical distribution of plants at different distances from the equator, and precisely parallel phenomena at different altitudes above the level of the sea at the same latitude. Explanation of the effect of excessive heat in *destroying* life. Too considerable an abstraction of heat may produce the same result by effecting some mechanical change inconsistent with vital action, or else it may merely *suspend* without *destroying* the power of vital action, producing the phenomenon of *dormant vitality*.

271. Influence of heat on the actions of animals. Distinction between warm and cold-blooded animals, as to the range of bodily and external temperature compatible with vital activity and the retention of vital power. Hence cold-blooded animals best exemplify the influence of this agent on the different functions; (1) nutritive functions; (2) on respiration and circulation; (3) nervous functions; (4) motorial power; (5) functions of the skin. See Carpenter, loc. cit. § 97 to § 141.

For a notice of other external conditions of vital activity, such as Electricity, Moisture, &c. See Ibid. § 142 to 162.

III.—Physiology of sleep.

272. Reasons for considering this topic in this connexion. The exercise of the functions being destructive to the organs, there arises a necessity for a periodical suspension of their activity in order that the waste may be repaired by nutritive reparation. This is true to some extent of all the vital operations attended with waste of substance, but is more strikingly characteristic of the functions of the cerebral and sensorial ganglia, the periodical suspension of which constitutes natural Sleep.

273. Phenomena of *profound* sleep, when the sensory ganglia as well as the cerebral hemispheres are inactive. Distinguished from *Coma* by the capability of being aroused by strong impressions. Doubt as to the condition of the cerebral hemispheres in profound sleep; but physiological analogies render it probable that they are entirely inactive and that *dreaming* is a phenomenon of imperfect sleep. Condition of the sensorial and cerebral ganglia in the latter case. Physiology of dreaming.

274. Periodical tendency to sleep, which may, however, be counteracted by strong determinations of the will, by unusual impressions on the senses, or by emotions of the mind. Influences which

favour the tendency. Access sometimes sudden, more frequently gradual. Intermediate stages between sleeping and waking. Amount required as affected by age, temperament, habits, exercise of body or mind, &c. Brief notice of the phenomena of somnambulism natural and induced, and of other states commonly referred to mesmerism and electro-biology.

IV.—Physiology of death.

275. The duration of the vital activity of every organism is limited, and the capacity for exhibiting vital actions is continually expended by every manifestation, so that death is "the necessary consummation of life." Different modes of *somatic* death, namely, (1) from *syncope* or suspension of the action of the heart, cutting off the supply of the blood which contains both material and dynamical stimuli indispensable to the action of all the tissues which will soon die on these stimuli being withheld. *Asthenia* or incomplete syncope. (2) *Asphyxia* or suspension of the aerating process whereby a stagnation occurs in the pulmonary circulation which necessarily puts a stop to the systemic circulation. Death from *Coma* belongs properly to this category, since the proximate cause of death is arrest of the aerating process by paralysis of the respiratory nervous centre. (3) *Necræmia*, or such an alteration of the blood as renders it unfit to support or stimulate the tissues. (4) From *congelation* "which stagnates *all* the vital operations."

276. *Molecular death* follows somatic after an interval varying with the characters of the tissues and organs. How molecular death of any other organ than one of the great centres of life, may lead to somatic death. Signs of apparent and real death.

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